Examining the trend of the research on the internet of things (IoT): A bibliometric analysis of the journal articles as indexed in the Scopus database

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Abstract. Studies related to the Internet of Things (IoT) has grown tremendously since 2010 even though this topic has been found published in Scopus since 1970. Several studies have been published in the Scopus database to analyse the trend in this topic. However, it does not account for the whole years (since 1970 up to 2019). This study employs a similar bibliometrics technique to study the trend in IoT by taking into account the first year it was published until today. Results show that this topic has grown extensively since 2010 until today. The top two journals are IEEE Internet of Things Journal and IEEE Access with more than 500 articles. This topic has been studied quite extensively in computer science and engineering discipline. Apart from IoT or “Internet of Things”, the top three keywords used are “wireless sensor networks”, “network security”, and “energy efficiency”. While most of the publications were written in English, the majority of the publications were contributed by Asian countries of which the English language is not their native language. The results of this study might contribute to the body of knowledge on providing comprehensive trend analysis of the studies related to IoT, which was published in the Scopus database from the year 1970 to 2019.

1. Introduction
The conversation about IoT topics has increased tremendously not only at the workplace but also in individual daily life. "Internet of Things" (IoT) has been defined as "diverse, everyday objects" that are connected to the information network where the objects "can take an active part in business processes" [1]. According to Morgan [2], IoT is a giant network of connected "things" which includes the relationship between people-people, people-things, and things-things. It connects any device with an on and off switch to the Internet, which includes everything from mobile phones, coffee makers, washing machines, headphones, lamps, wearable devices and others [2].

Studies related to IoT has grown tremendously since 2010 even though this topic has been found published in Scopus since 1970. Many studies related to IoT has been conducted in various fields, and concepts such as the factors contribute to the implementation of IoT, the impact of IoT on related fields, and the evolution of the IoT studies (such as bibliometrics analysis and literature review studies). Bibliometrics analysis has been used to assess the scientific disciplines, production, and databases, and it provides valuable tools to describe scientific activity in the past and to orient future
research [3]. 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 [4]. The bibliometric studies are used to evaluate the productivity and the quality of the research of the scientists [5] and gains popularity as one of the approaches in revealing research trend [6]. Bibliometric research allows the identification and description of a series of patterns in the production of scientific knowledge.

There are a few studies that have been conducted to see the pattern and growth of IoT using bibliometric analysis. For example, Lu [7] conducted a bibliometric analysis on IoT related kinds of literature collected from CNKI database in China from 2003 to 2017. It analyses the annual distribution of IoT literature, authors and institutions, topics, disciplines and patents and standards, and reviews the status of IoT in China. The conclusion is that China's Internet of Things research is currently in a stage of rapid development. Kumarswamy, Riyaz and Chaman [8] also conducted a bibliometrics analysis study which focuses on paper related to the Internet of things (IoT) research in India for five years (2015-2019) based on the web of science database. The study analysis data with regards to years, document type, language, institutions, authors, journals, and publications related to IoT discipline in India. Their study found that India has produced 645 research papers where most of the publications (588) received form article type. All papers are published in the English language except for one research publication which is published in the German language.

Nascimento et al. [4] conducted a study to map the scientific production on the IoT from the Web of Science database between the period from 2010 to 2018. They found 2,446 publications related to the topic where the year with the highest number of publications was in 2018, with 932 publications. Their study analyses data with regards to years of publications, prominent authors, language used in the publication, areas of discipline, journals, institutions, and country of highest publications.

MacDonald and Dressler [9] conducted a study using the Web of Science database for articles published between 2000 to 2016. Data were collected from 2375 articles. Their study used three methods to analyse their data, namely, citation analysis, bibliographic coupling, and keyword co-occurrence to present their results. Results were presented for highest countries published IoT articles, most influential journals, most keywords used, and most research areas. While the previous studies focused on the Web of Science and CNKI database, this study, however, presents the results based on the Scopus database. Thus, this paper aims to briefly present the latest trend of the research on the internet of things based on the journal articles as indexed in the Scopus database. This paper also extends the study conducted by Erfanmanesh and Abrizah [10], who also focused on the same topic but only covered for the period from 2011-2016.

2. Methods
This study employs the Scopus database as a basis to extract published works on IoT as of July 2019. Scopus database has been used since it contains high indexed peer-reviewed documents [11], the most effective search engine [12], the largest and the most comprehensive global abstracts and citation database [10]. There are abundant of studies conducted on bibliometric analysis have been done using the Scopus database compared to other databases such as Web of Science, Scimago, Pubmed, Ebscohost and Dimensions. The specific search query “TITLE ( iot OR "internet of thing" ) AND ( LIMIT-TO ( PUBSTAGE , "final" ) ) AND ( LIMIT-TO ( DOCTYPE , "ar" ) )” has been conducted to search the articles on IoT or Internet of Things. This study restricted the query to the title of the documents, documents that are in the final stage of publication and published in journals only. Based on this search approach, a total of 8,572 journal articles were retrieved. These articles were then further analysed using Microsoft Excel.

3. Results
This section will present the results and analysis of 8,572 articles published in the Scopus journal database in terms of the evolution of published studies, language used in the articles studied, subject areas, most influential journals, top occurrence keywords, and most influential countries.
3.1. Evolution of published studies
This section shows the analysis of publications concerning IoT. Table 1 shows the number of publications between 1970 and 2019, which shows a growing interest in the subject. The number of publications was steady before 2012, where it increased slowly in 2010. Since 2012, the numbers grow significantly year by years, and until 2016, the numbers had grown tremendously from 553 in 2015 to 1,030 in 2016. It is expected that the numbers in 2019 will outrage the total number published in 2018 as the data collected was until July 2019.

Table 1. Year of Publications.

| Year     | No. of Articles | Percentage (%) |
|----------|-----------------|----------------|
| Before 2010 | 72              | 0.84           |
| 2011     | 80              | 0.93           |
| 2012     | 166             | 1.94           |
| 2013     | 251             | 2.93           |
| 2014     | 356             | 4.15           |
| 2015     | 553             | 6.45           |
| 2016     | 1,030           | 12.02          |
| 2017     | 1,496           | 17.45          |
| 2018     | 2,601           | 30.34          |
| 2019     | 1,967           | 22.95          |
| **Total** | **8,572**       | **100.00**     |

The first paper published in Scopus was in the year 1970. Since then, the publication did not show any significant growth until 2010. In the year 2011 onwards that publication of IoT has grown steadily until 2016, where it increased significantly to 1,030 publications. The growth keeps arising until 2018 with 2,601 publications. It is expected that publications in 2019 will outnumber the total publications in 2018 as until July 2019, the publications have reached nearly 2,000 articles.

3.2. Languages of documents
Table 2 presents the language used in the IoT publications. Similar to previous studies [4, 8], English is the dominant language in IoT publications with 94.49 percent. Next, is Chinese with 3.81 percent, followed by other languages with less than one percent.

Table 2. Languages Used for Publications.

| Languages    | No. of Articles | Percentage (%) |
|--------------|-----------------|----------------|
| English      | 8,117           | 94.49          |
| Chinese      | 327             | 3.81           |
| Japanese     | 42              | 0.49           |
| German       | 26              | 0.30           |
| Spanish      | 21              | 0.24           |
| Korean       | 12              | 0.14           |
| Portuguese   | 11              | 0.13           |
| Persian      | 5               | 0.06           |
| French       | 4               | 0.05           |
| Russian      | 3               | 0.03           |
| Polish       | 2               | 0.02           |
| Czech        | 1               | 0.01           |
| Turkish      | 1               | 0.01           |
| **Total**    | **8,572**       | **100.00**     |
3.3. Subject area

Figure 1 presents the subject areas related to IoT. It could be seen that the IoT has been quite a popular term to be studied and published in various fields in science and social science areas. The top ten subject areas are computer science, engineering, physics and astronomy, material science, mathematics, biochemistry, genetics and molecular biology, chemistry, business, management and accounting, social sciences, and environmental science. Computer science and engineering areas dominated the publications in IoT with 34.4 percent and 29.4 percent respectively.

![Figure 1](image)

**Figure 1.** Articles by subject area

3.4. Source title

Table 3 lists the leading journals for publications on the IoT with more than 100 articles. The top two journals are IEEE Internet of Things Journal and IEEE Access with more than 500 articles. The result is in line with the study conducted by MacDonald and Dressler [9] who found that IEEE Internet of Things is the among top three leading journals in this area. Sensors Switzerland published nearly 400 articles. Five journals are also considered as the influential source in the IoT area namely, International Journal of Innovative Technology and Exploring Engineering, IEEE Communications Magazine, International Journal of Distributed Sensor Networks, IEEE Transactions on Industrial Informatics, and International Journal of Recent Technology and Engineering.

**Table 3.** Most influential source title with more than 100 Articles

| Source Title                                                                 | No. of Documents |
|------------------------------------------------------------------------------|------------------|
| IEEE Internet Of Things Journal                                              | 539              |
| IEEE Access                                                                  | 502              |
| Sensors Switzerland                                                          | 394              |
| Future Generation Computer Systems                                           | 236              |
| International Journal of Innovative Technology and Exploring Engineering     | 134              |
| IEEE Communications Magazine                                                 | 133              |
| International Journal of Distributed Sensor Networks                         | 129              |
| IEEE Transactions on Industrial Informatics                                  | 103              |
3.5. Keywords analysis

Table 4 lists the keywords that are used along with the “Internet of Things” and/or “IoT” keywords, which occurred more than 200 times in the articles studied. The top three keywords used are “wireless sensor networks” (595 articles), “network security” (568 articles), and “energy efficiency” (505 articles) which these keywords are most related to engineering or computer science. Only one keyword that may relate best to social science, namely “decision making”.

Table 4. Keywords with more than 200 occurrences

| Author Keywords                                    | No. of Occurrences |
|---------------------------------------------------|--------------------|
| Wireless Sensor Networks                          | 595                |
| Network Security                                  | 568                |
| Energy Efficiency                                 | 505                |
| Cloud Computing                                   | 496                |
| Energy Utilization                                | 477                |
| Security                                          | 439                |
| Automation                                        | 391                |
| Sensor Nodes                                      | 380                |
| Network Architecture                              | 369                |
| Big Data                                          | 365                |
| Cryptography                                      | 360                |
| Internet Protocols                                | 349                |
| Authentication                                    | 344                |
| Wireless Telecommunication Systems                | 337                |
| Digital Storage                                   | 333                |
| Sensors                                           | 326                |
| Information Management                            | 293                |
| Monitoring                                        | 281                |
| Distributed Computer Systems                      | 279                |
| Quality Of Service                                | 278                |
| Radio Frequency Identification (RFID)              | 276                |
| Data Privacy                                      | 266                |
| Intelligent Buildings                             | 259                |
| Data Handling                                     | 257                |
| Smart City                                        | 251                |
| Mobile Telecommunication Systems                  | 250                |
| Gateways (computer Networks)                      | 226                |
| Edge Computing                                    | 222                |
| Decision Making                                   | 211                |
| Embedded Systems                                  | 208                |

3.6. Most influential countries

Table 5 presents the countries contributed to the IoT publication in Scopus journals. A total of 9,724 articles were found as some articles were contributed by more than one country. Therefore, the total does not match with the total publications which are 8,572. The table shows that Asian countries contributed to the majority of the publications related to IoT. China and India are the most two top contributor countries not only among Asian countries but also among all the countries with a total publication of 2,451 and 1,226, respectively. The following contributors are the European countries
with 2,133 publications. The least is the Oceanian countries, representing by Australia with 285 publications.

Table 5. Countries contributed to the publications

| Country         | No. of Articles | Percentage (%) |
|-----------------|-----------------|----------------|
| **Asian Countries** |                 |                |
| China           | 2,451           | 28.59          |
| India           | 1,226           | 14.30          |
| South Korea     | 999             | 11.65          |
| Taiwan          | 263             | 3.07           |
| Japan           | 249             | 2.90           |
| Saudi Arabia    | 199             | 2.32           |
| Pakistan        | 173             | 2.02           |
| Malaysia        | 168             | 1.96           |
| **Total**       | 5,728           | 66.81          |
| **European Countries** |         |                |
| United Kingdom  | 496             | 5.79           |
| Italy           | 419             | 4.89           |
| Spain           | 336             | 3.92           |
| France          | 203             | 2.37           |
| Germany         | 185             | 2.16           |
| Sweden          | 141             | 1.64           |
| Finland         | 134             | 1.56           |
| Greece          | 117             | 1.36           |
| Portugal        | 102             | 1.19           |
| **Total**       | 2,133           | 24.88          |
| **American Countries** |       |                |
| United States   | 1,192           | 13.91          |
| Canada          | 249             | 2.90           |
| Brazil          | 137             | 1.60           |
| **Total**       | 1,578           | 18.41          |
| **Oceanian Countries** |     |                |
| Australia       | 285             | 3.32           |
| **Total**       | 285             | 3.32           |

4. Conclusion

The topic related to IoT has grown extensively since 2010 and is growing tremendously in the future due to the industrial revolution 4.0 waves that change not only one’s work-life but also personal life. Even though this topic has been studied quite extensively in the computer science and engineering discipline, social science discipline is catching up. One of the essential keywords in a social science discipline, namely “decision making” has been found as among the top popular keywords. It is quite interesting to note that while most of the publications were written in English, the majority of the publications were contributed by Asian countries of which the English language is not their native language. The results of this study might contribute to the body of knowledge on providing comprehensive trend analysis of the studies related to IoT, which was published in the Scopus database from the year 1970 to 2019.
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