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## Recent Trends in Cloud Computing and Edge Computing

Sonali Deshpande

MIT School of Engineering, MIT ADT University, sonali.deshpande@mituniversity.edu.in

Nilima Kulkarni

MIT School of Engineering, MIT ADT University, nilima.kulkarni@mituniversity.edu.in

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# Recent Trends in Cloud Computing and Edge Computing

**Sonali Deshpande,**

Department of Computer Science & Engineering  
MIT School of Engineering, MIT ADT University Pune-412201  
sonali.deshpande@mituniversity.edu.in

**Nilima Kulkarni**

Department of Computer Science & Engineering  
MIT School of Engineering, MIT ADT University Pune-412201  
nilima.kulkarni@mituniversity.edu.in

## ABSTRACT

**Background:** This study aims to analyze the work done in domain of cloud computing and edge computing using artificial intelligence from 2015 to 2021. Recent research shows the bibliometric methods are useful for such kind of analysis. Thus in this paper analysis is carried out using the bibliometric methods.

**Methods:** different articles on edge computing and edge intelligence were retrieved using one of the most popular database- Scopus. The research articles are considered between 2015 to 2021. Scopus analyzer is used for getting some analysis results such as documents by year, source, country and so on. VOSviewer Version 1.6.16 is used for the analysis of different units such as co-authorship, co-occurrences, citation analysis etc.

**Results:** In our study, a database search outputs a total of 204 articles on edge intelligence from 2015 to 2021. Statistical analysis and network analysis shows the maximum articles are published in the years 2019 and 2020 with China contributed the largest number of documents. Network analysis of different parameters shows a good potential of the topic in terms of research.

**Conclusions:** Scopus keyword search outcome has 204 articles with English language having the largest number. Authors, documents, country, affiliation etc are statically analyzed and indicates the potential of the topic. Network analysis of different parameters indicates that, there is a lot of scope to contribute in the further research in terms of advanced algorithms of artificial Intelligence.

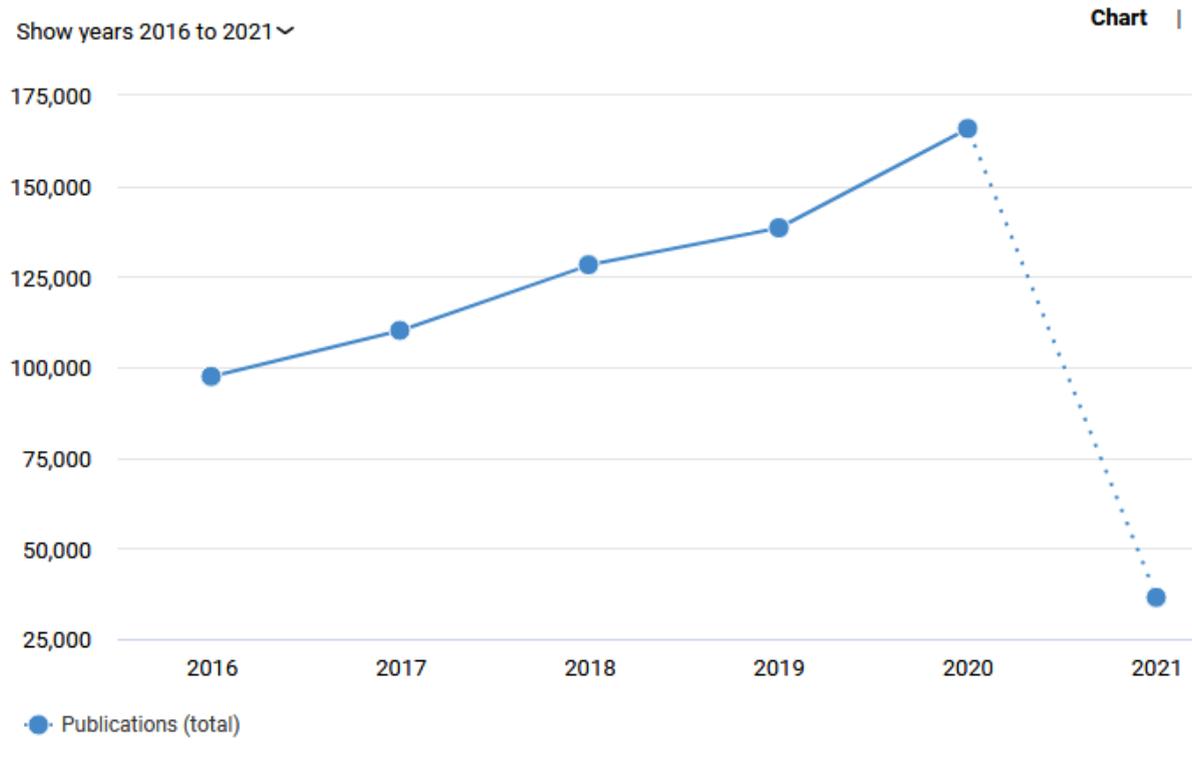
**Keywords:** Cloud Computing, Edge computing, Fog computing and Edge intelligence.

## I. INTRODUCTION

Edge computing is inspired by the concept of Content Delivery Networks, which aims to bring the internet closer to users. Data and computation are brought closer to the user with edge computing. Data and computations are localized in edge computing, which means it takes less time to respond and requires less bandwidth[1]. Edge computing magnifies the storage, processing power of data generated by connected devices. Edge is located at edge of the network. It is new concept in computing which brings cloud computing services and utilities closer to end users. Edge computing manages computational data, services and applications on edge network. Edge computing contains different heterogeneous devices which communicates with network and perform task like storage of data and processing of data. Edge Computing combines several technologies, including Cloud Computing, Grid Computing, and Internet of Things (IoT). It adds a tier between the Cloud and the end-devices, bringing computational power as close as possible to the end-device.[2-6] Edge computing has three major models are 1.Cloudlets 2.Fog Computing 3.Mobile Edge Computing. European Telecommunications Standards Institute [7-9] has given these models where in Cloudlets we can access cloud by using resources of computer which are available in local network. Fog Computing allows applications to run directly on the network's edge. Users of Mobile Edge Computing can use Base Station computing services. The Internet's edge is a singular location. It's ideal for low-latency offload infrastructure to support emerging applications like augmented reality, public safety, connected and autonomous driving, smart manufacturing, and healthcare because it's typically only one hop away from associated end devices[11][15]. Figure 1 show that number of paper published related to edge computing in the year 2016 to 2021. IOT generates tremendous data in form of new business insights, automating business and production processes etc data must be analyzed and processed at the edge of WAN [12-14] in order to maximize the capture, delivery, processing, analysis and storage of what can quantity of petabytes of data every day Edge computing helps to address cost, bandwidth and latency issue across a broad range of IOT application, here are the reason why we need edge computing.

1. The amount of data generated is enormous than the network's ability to process it, so send the data to edge computing device instead of sending the data to clouds (Reduce the amount of cloud data that is transmitted and stored).[15][17]
2. To transmit the data to cloud process that data and to take appropriate action at the end requires more time and latency also, so this can be done on the edge device (Reduce the lag time in data transmission and processing).[16]

3. Edge computing helps to prioritize data that needs attention.



The visualization shows the number of publications published in each year.

Figure 1: Number of papers published related to “Edge Computing” on Google scholar.

## II. MATERIALS AND METHODS

### 2.1 Primary Database Collection

There are many popular databases worldwide, such as scopus, web of science, google scholar, scimago etc. These databases are having a very wide range of publications. Out of these scopus- the most popular and one of the largest database, is used for the analysis. The keywords are used for search have given a total of 204 number of publication results. The different keywords are used for the searching of the databases across the world. There is no any restriction on country, language etc. Each publication has the information such as author, country, citations, documents, sources etc. This information is used for the analysis.

Thus the query for searching the documents in Scopus is:

( TITLE-ABS-KEY ( edge AND computing ) AND TITLE-ABS-KEY ( fog AND computing ) AND TITLE-ABS-KEY ( cloud AND computing ) AND TITLE-ABS-KEY ( edge AND intelligence ) )

## 2.2 Initial Search Outcomes

On the Scopus database, using the different keywords related to our work, the publications are obtained. These are analyzed according to the language. It is found that, English language has the highest number of publications of 204, followed by Chinese.

**Table 1: Language Trends of Publications**

Language of publishing	Publication count
English	203
Chinese	1

Source: <http://www.scopus.com> (assessed on 4<sup>th</sup> March, 2021)

## III. PERFORMANCE ANALYSIS

VOS viewer 1.6.16 [19][28] is the software that is used for the database analysis in addition to the analysis form Scopus. It provides a very effective way to analyze the co-citations, co-occurrences, bibliometric couplings etc. Following types of analysis is performed. Statistical Analysis of Databases

1. Documents by author
2. Documents by Country
3. Documents by year
4. Documents by subject area
5. Documents by Source
6. Documents by Type
7. Documents by affiliation

### Network Analysis of Databases

1. Co-authorship: Authors, organizations, country
2. Co-occurrence: All keywords, Author keywords, Index keywords
3. Citation Analysis: Sources, authors, organizations, country
4. Bibliographic coupling: Documents, Authors

## IV. RESULTS AND DISCUSSION

Analysis is performed by two different ways, statistical analysis of database and network analysis.

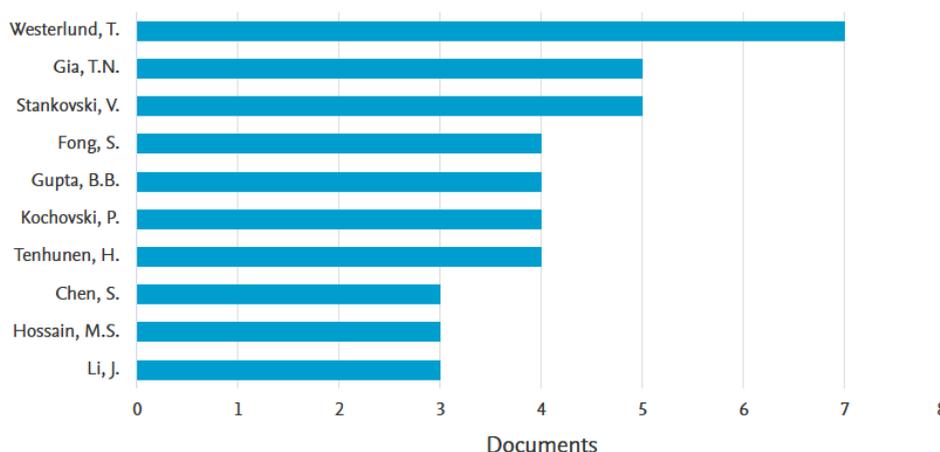
### 4.1 Statistical Analysis

#### 4.1.1 Documents by Author

In this analysis, authors with the number of publications are considered. Publications with a very large number of authors (15) are excluded. Top 10 authors with this comparison are shown here. It is found that WesterlundT [5-7] has the highest number of publications of 7 in this area. Maximum authors have an approximate average publication count 4 to 5.

#### Documents by author

Compare the document counts for up to 15 authors.



**Figure 2: Analysis of Publications by Document by author**  
Source: <http://www.scopus.com> (assessed on 4<sup>th</sup> March 2021)

#### 4.1.2 Analysis of Publications by Country or Territory

Scopus database is analyzed for countries by considering the number of documents published. It shows that China has the highest number of documents published between the elected timeline. It is followed by United States and then India.

#### 4.1.3 Documents Analysis by year

Documents are collected from scopus database in the year 2011 to 2021 including different sources such as conferences, journal, book chapter etc. The table shows the statistical information and graphical representation is as shown in figure. It is observed from the

analysis that, highest number of publication is in the year of 2019 followed by 2020. This shows that, there is a good scope for working in this area in the preceding years.

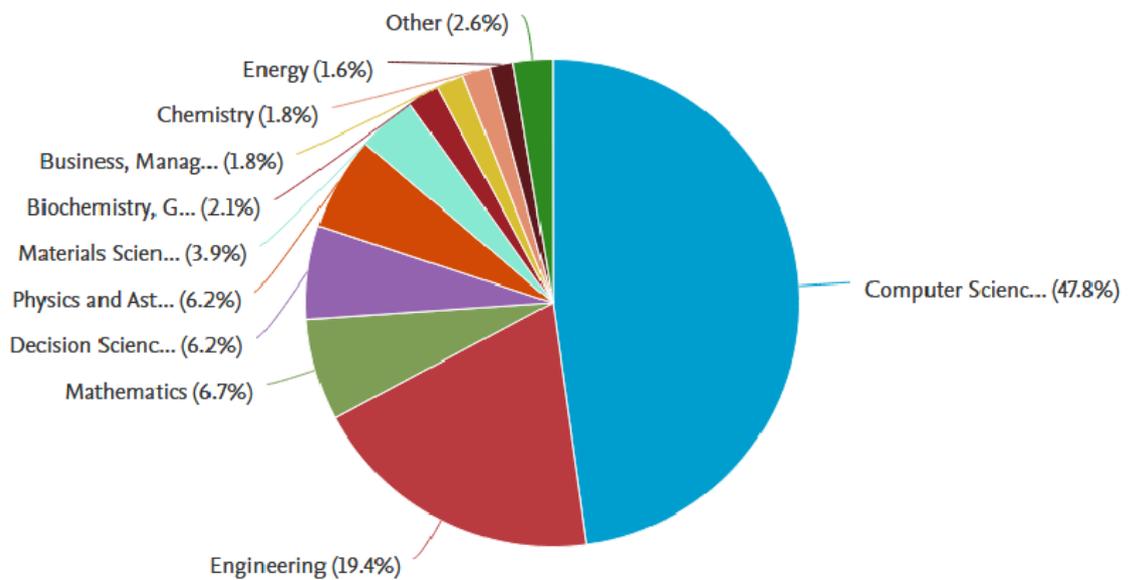
**Table 2: Number of Publication by Year**

Year	Number of Publications
2021	18
2020	59
2019	46
2018	40
2017	29
2016	6
2015	6
<b>Total</b>	<b>204</b>

Source: <http://www.scopus.com> (assessed on 4<sup>th</sup>March. 2021)

#### 4.1.4 Documents by Subject Area

Documents by subject area



**Figure 3: Analysis of Documents by Subject Area**

Source: <http://www.scopus.com> (assessed on 4<sup>th</sup>March 2021)

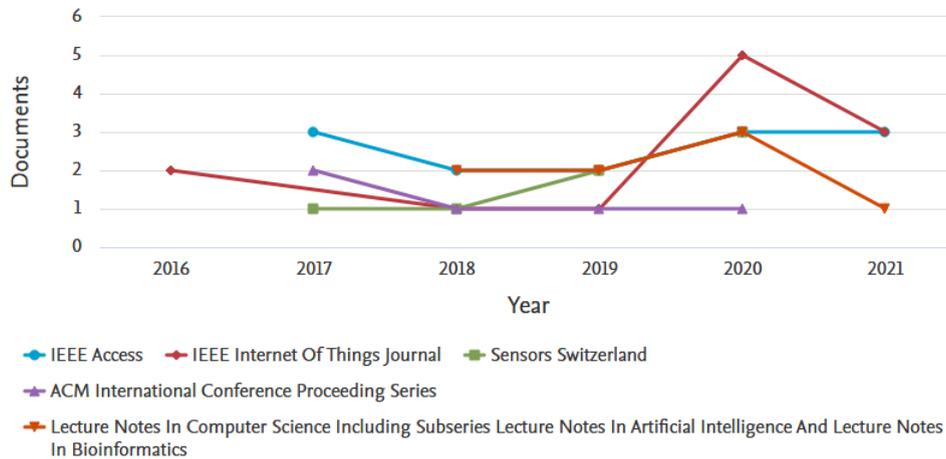
#### 4.1.5 Document Analysis by Sources

Database indicates different sources such as conferences, journal, book chapter, notes, and reviews and so on. Year-wise publication statistics are shown in the table. Figure shows the graphical representation of the different sources with number of documents published year-wise.

Documents per year by source

Compare the document counts for up to 10 sources.

[Compare sources and view CiteScore, SJR, and SNIP data](#)



**Figure 4: Analysis of Documents by Sources**

Source: <http://www.scopus.com> (assessed on 4<sup>th</sup>March. 2021)

#### 4.1.6. Documents by Type

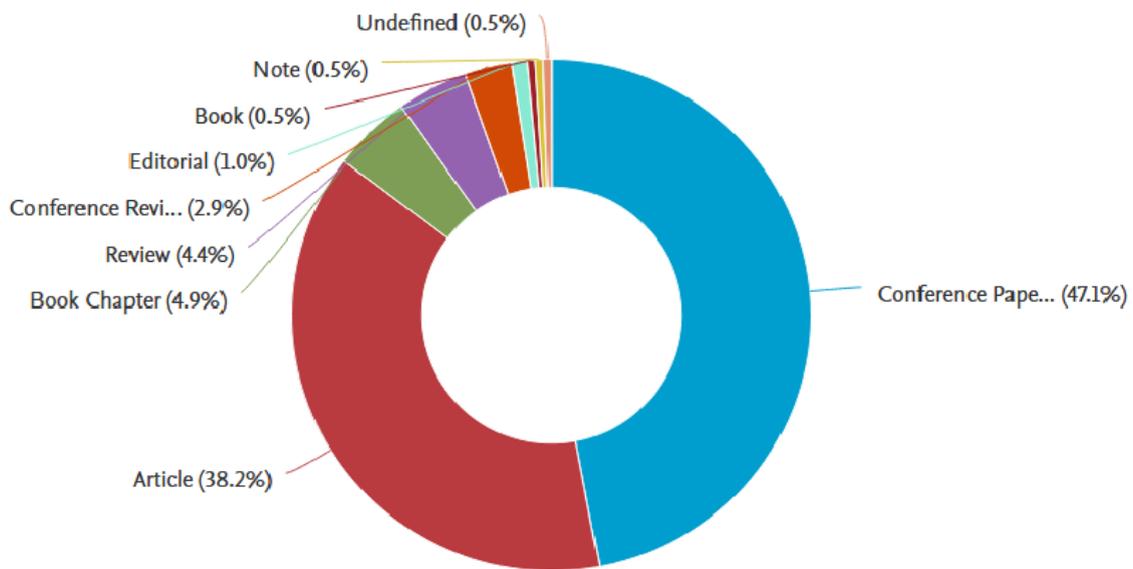
It is seen from the analysis that, most of the publications are journal articles followed by conference papers.

**Table 3: Analysis by Document Types**

Sr. No.	Document type	Publications
1.	Journal	92
2.	Conference Proceeding	85
3.	Book Series	20
4.	Book	6
5.	Trade Journal	1
<b>Total</b>		<b>204</b>

Source: <http://www.scopus.com> (assessed on 4<sup>th</sup>March 2021)

## Documents by type



Activate Windows

**Figure 5: Analysis of Publications by Document Type**

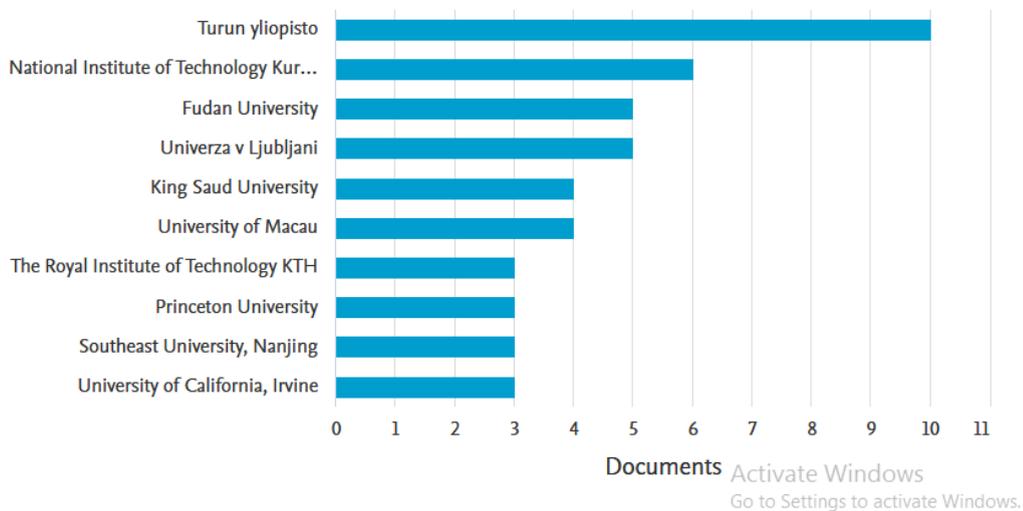
Source: <http://www.scopus.com> (assessed on 4<sup>th</sup> March 2021)

### 4.1.7 Documents by Affiliations

In this analysis, top 15 affiliations are considered. It is found that, University Turun yliopisto. More than half of the affiliations have at least 5 publications related to this field.

#### Documents by affiliation

Compare the document counts for up to 15 affiliations.



Documents

Activate Windows  
Go to Settings to activate Windows.

**Figure 6: Analysis of Publications by Document by affiliation**

Source: <http://www.scopus.com> (assessed on 4<sup>th</sup> March 2021)

### 4.1.8 Analysis by Funding Sponsors

In this case, China is ahead amongst all, with highest funding to the National Nature Science Foundation, China. Analysis found most of the funding institutes.

#### Documents by funding sponsor

Compare the document counts for up to 15 funding sponsors.

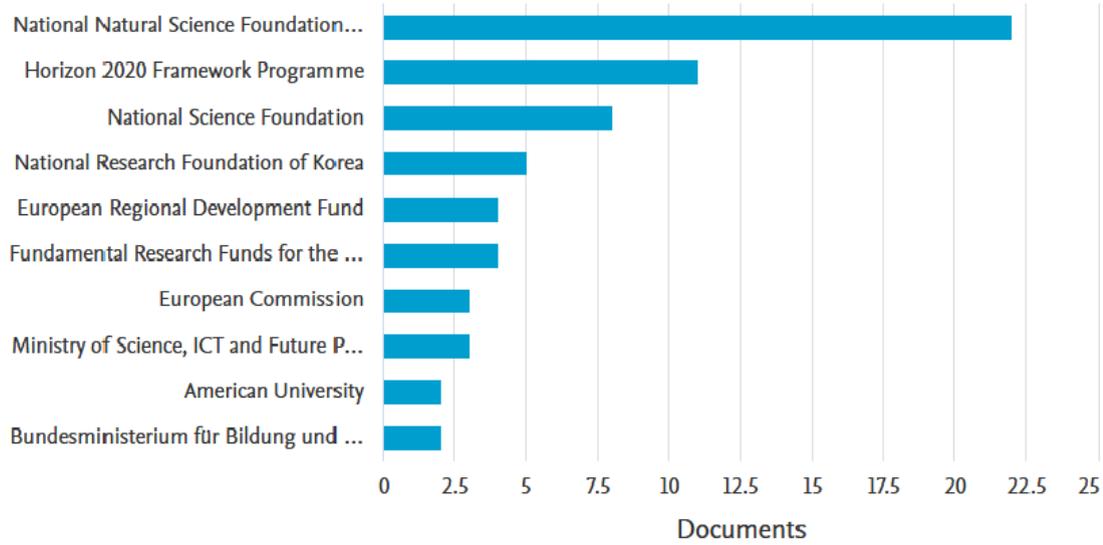


Figure 7: Analysis of Publications by Funding Sponsors

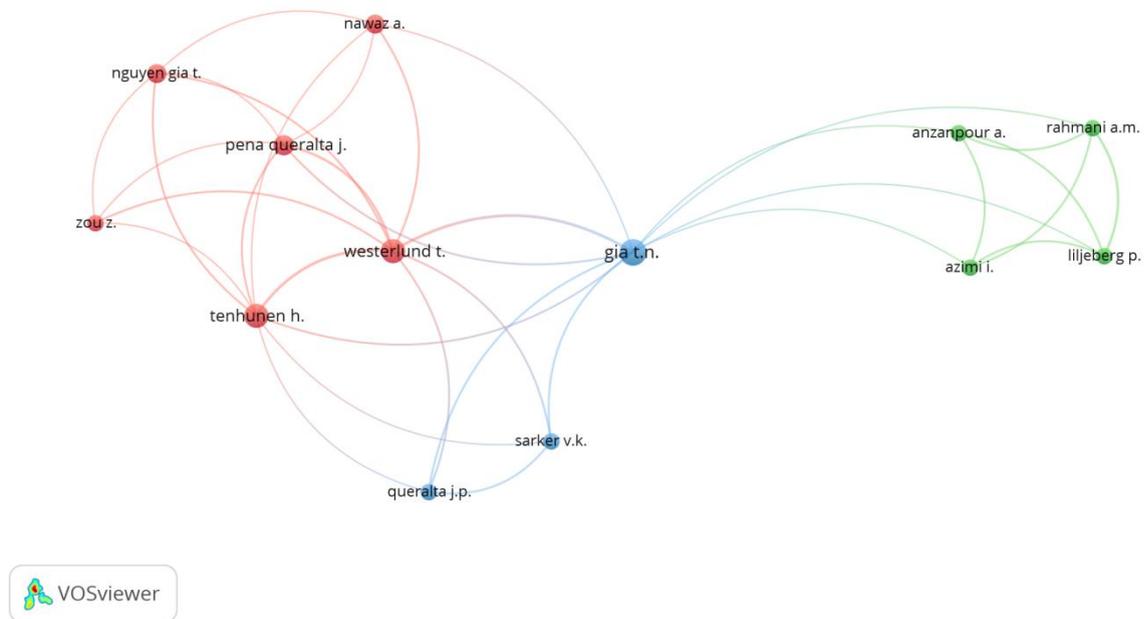
Source: <http://www.scopus.com> (assessed on 4<sup>th</sup> March 2021)

## 4.2 Network Analysis

### 4.2.1 Co-authorship Analysis

#### A) Co-authorship in terms of Authors

This parameter of analysis is considered with 03 different parameters related to it. The authors, organizations, and countries are considered for analyzing this parameter [29]. Documents with a very large number of authors are ignored in this analysis. This number is considered to be 25. Threshold is considered as 2 for minimum number of documents of an author. It is seen that out of 642 authors, 66 authors met the criteria. The total strength of the co-authorship is calculated with other authors. By this method, the link strengths are obtained. Westerlund t found the highest link strength of 21 with the total number of citations to be 1096 for 7 different documents. Here total of 66 authors found to have the relation in terms of co-authorship. So these are only shown in the figure.



**Figure 8: Co-authorship Network Analysis in Terms of Authors**  
 Source [www.scopus.com](http://www.scopus.com), accessed on 4<sup>th</sup> March 2021

### **B) Co-authorship in terms of Country**

Co-authorship can also be obtained in relation to the country. A total of 63 countries are there, in which this databases are present. After considering the threshold of minimum 5 documents in a country, 17 countries met the threshold. Here, United States found to have the highest citations of 2116, and the link strength of 29, that is also highest amongst all. As far as the numbers of document are concerned, China has the highest of all that is 42.



## B) Co-occurrence analysis in terms of Author keywords

Co-occurrence of author keywords is analyzed with the minimum threshold of 5 per author. Out of 560 keywords by the authors, 17 keywords met the threshold.

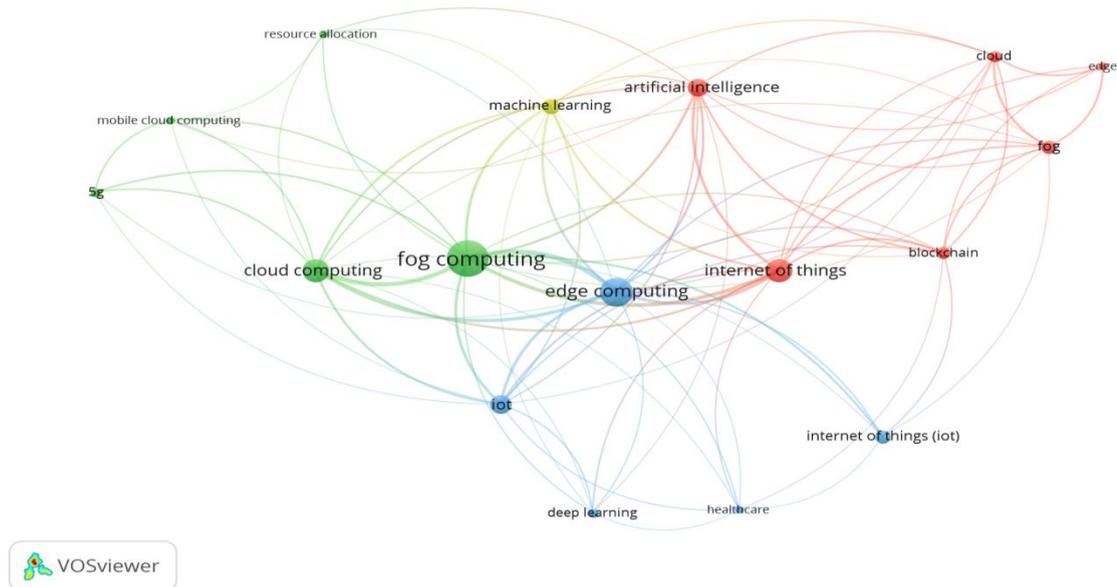


Figure 11: Co-occurrence Network Analysis (Author Keywords)

Source [www.scopus.com](http://www.scopus.com), accessed on 4<sup>th</sup> March 2021

## C) Co-occurrence in terms of Index Keywords

Co-concurrence is also considered by index keywords of 1517, only 77 met the threshold.

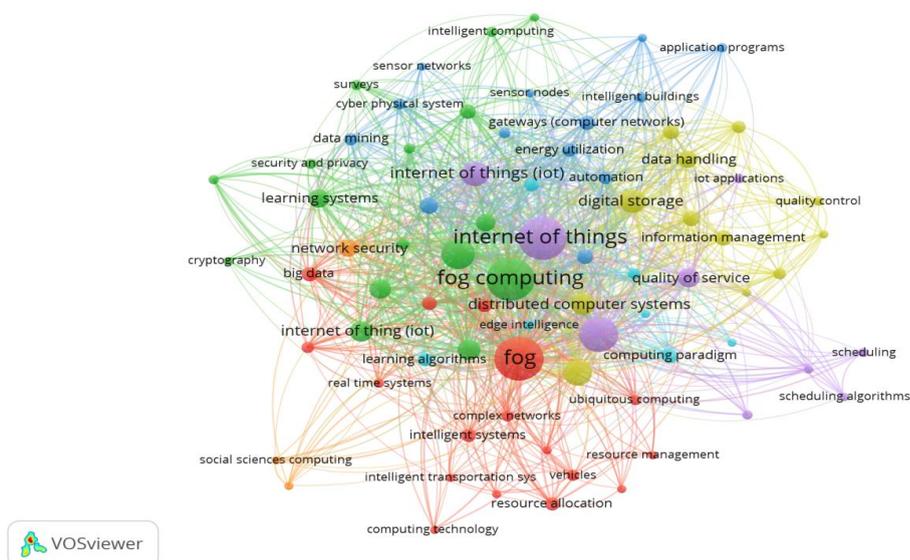


Figure 12: Co-occurrence of Index Keywords

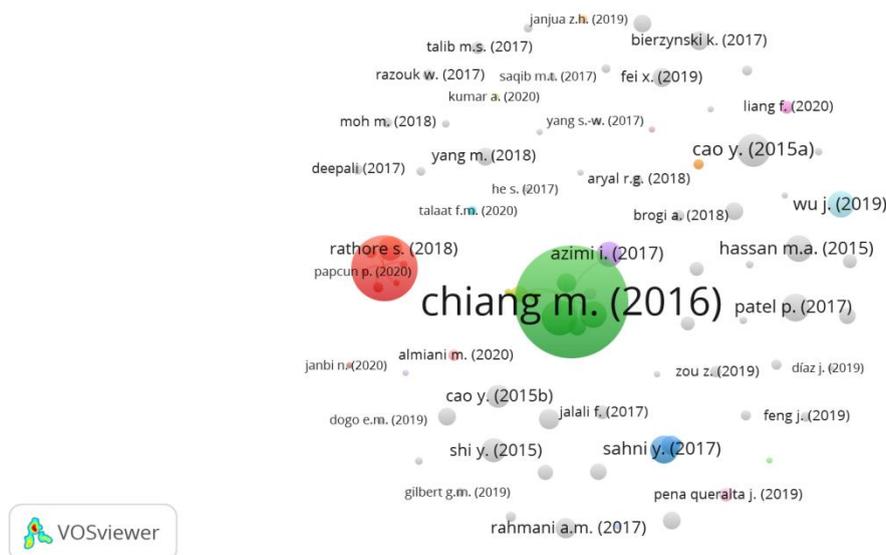
Source [www.scopus.com](http://www.scopus.com), accessed on 4<sup>th</sup> March 2021

### 4.2.3. Network Analysis of Citations

This analysis is done with the units of analysis including documents, sources, authors, country and organization.

#### A) Citation Analysis of Documents

Out of total of 210 documents, minimum 5 citations are considered as a threshold per document. So 86 documents met the threshold. Chiang m (2016) has the highest number of citations 1094 while the link strength is the highest for Chiang m 8 (2016).

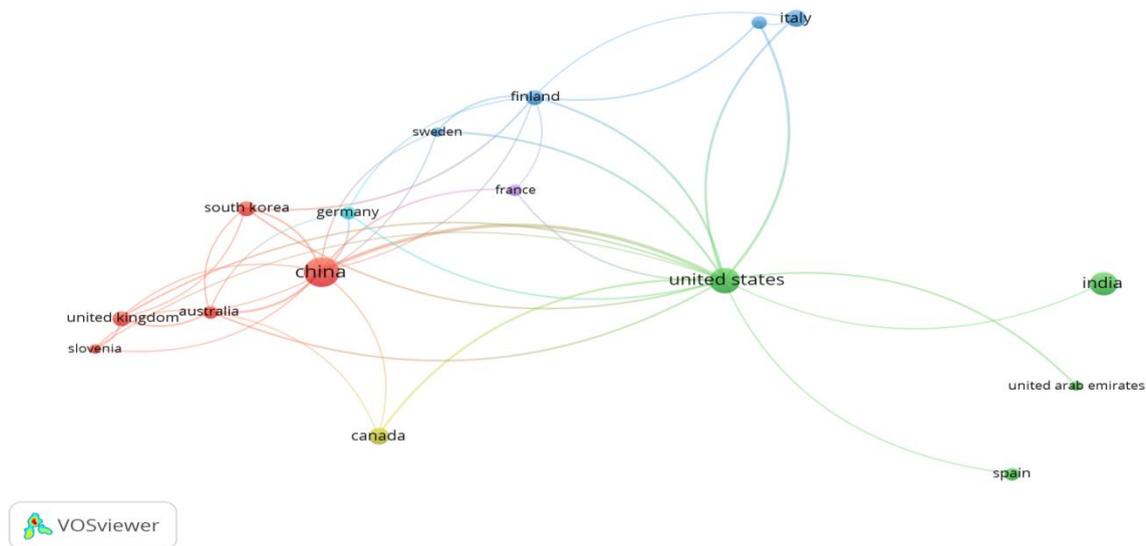


**Figure 13: Network Analysis of Citations (In terms of Documents)**

Source [www.scopus.com](http://www.scopus.com), accessed on 4<sup>th</sup> March 2021

#### B) Citation analysis by country

Total of 63 countries have the databases of the leukemia work. Out of which 17 meet the citation criteria considering a threshold of minimum 5 citations per country.



**Figure 14: Citation analysis of country**  
 Source [www.scopus.com](http://www.scopus.com), accessed on 4<sup>th</sup> March 2021

## V. CONCLUSION

Bibliometric survey on edge computing, fog computing and edge intelligence is carried out by considering the most popular and the largest database used worldwide- Scopus. The database is considered from the year 2016 to 2020. By using the keyword search with AND operator and OR operator the database searching is done. A total of 204 documents are obtained as the outcome of the search.

The different parameters are considered for analysis of this database. It is seen that English language has most of the documents 42 followed by Chinese. The outcome of Keyword search indicates that maximum publications are with the keyword “*fog computing.*” Maximum documents are published in the year 2020 followed by the year 2019. The subject area Computer Science and Engineering covered almost 47.8% of the documents. As far as, the type of document is considered, papers of conference are the major occupants followed by the articles. The analysis of countries proved, China has the highest number of documents within the periods. Documents by different authors also analyzed and maximum authors average Publications account 5 to 7. The highest numbers of documents are Westerlund t.

The network analysis is also done by VOS viewer 1.6.16 version software. The different analysis types such as co-authorship analysis co-occurrence analysis citation analysis and bibliographic coupling are done with the same database. All these different network analysis indicates a quite significant information about different mentioned above. It could also be

seen that the major work in edge computing is done in 2019 and 2020. In upcoming years a very vast and major work is expected in this area.

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