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Research Trend of Internet of Things (IoT): A Scientometric Review

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Abstract: The present study deals with the open-access Internet of Things (IoT) research in the global output for the span of ten years based on the Web of Science (WoS) core collection database, during the period 2011-2020. The main aims of the study are - a scientometric output of all open access internet of things (IoT) research, in respect of the growth of research output, relative growth rate and doubling time, year-wise distribution, language-wise distribution, country collaboration, most prolific authors, most prolific journals, most relevant authors keywords, conceptual structure map, and intellectual structure. The highest number of records published is 3700 in 2020 out of 10628 on open access IoT research, whereas the year 2011 is marked for holding the lowest position having only 18 records during the study period. In this study, among the top 20 authors, Zhang Y is in the top position by publishing 73 articles, getting citations 1143, h-index 13, g-index 33, and m-index 0. China is registered as the most productive country with 3092 world publications share. The majority of publication in open access IoT has been published in the form of IEEE Access in most relevant source with 2504 publications, total citation 24248, h-index 63, g-index 111, and m-index 7.875. This study indicates the relative growth rate and doubling time of open access IoT research across the globe irrespective of citation count, collaboration rate, and so on.

Keywords: IoT, Internet of Things, Global Output, Collaboration, Bibliometrix Package, h index, g index, m index, Scientometrics

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1. Introduction

In the contemporary world, Internet has played an important role in every aspect of human life. Its progress is spearheaded by mobile devices, which have gradually become the integral part of our daily life, as everyone desires to be linked to the Internet all the time. The Internet of Things (IoT) concept was invented by Kevin Ashton in 1999 during his work at Procter & Gamble. Working in that company, he attracted his senior management's attention to a new technology called Radio Frequency Identification (RFID) for supply chain optimization purpose. As the internet was the most recent trend in 1999 and as it somehow made sense, he called his presentation "Internet of Things" (**Lueth, 2014**). The Internet of things (IoT) general depiction is defining as "Internet of things (IoT) is a network of physical objects. The internet is not only a network of computers, but it has evolved into a network of the device of all type and sizes, vehicles, smartphones, home appliances, toys, cameras, medical instruments and industrial systems, animals, people, buildings, all connected, all communicating & sharing information based on stipulated protocols to achieve smart reorganizations, positioning, tracing, safe & control & even personal real-time online monitoring, online upgrade, process control & administration" (**Vermesan & Friess, 2013**). They have defined the Internet of things into three types as below: "Internet of things is an internet of three things" as (a) People to people, (b) People to machine /things, and (c) Things /machine to things /machine, Interacting through the internet (**Patel et al., 2016**). Nowadays, the techniques of IoT have become more and more popular for collecting sensing data and building intelligent services and applications, and its highly interconnected network of heterogeneous entities such as tags, embedded services, hand-held services, and back-end servers. Some organizations (e.g., M2M) (**Cao et al., 2016**).

2. Review of Related Studies

B. H et al., (**2019**) examined a scientometric study of Indian publications on Internet of Things (IoT) research. They have used 645 research papers published during 2015-2019 and identified different growth of research output and citations, relative growth rate, and doubling time, subdiscipline wise distribution of publications, highly productive authors, highly preferred journals and highly cited publications, highly productive institutions, national and international collaboration in IoT research. The top 20 Indian organizations have been taken into account for this study, where 644 research papers were published in the English language and only one research article was published in the German language. Other researchers examined 6800 global publications on the Internet of Things (IoT) for 10 years with 2005-2014 as the study period.

The authors identified characteristics of highly contributing countries, authors, annual average growth rate, and citation. The most productive countries sequentially were China (44.87%), the USA (8.04%), Germany (6.06%), and the UK (4.84%) during the said study period (**Gupta et al., 2013**). **Chandra (2018)** conducted a scientometric study to visualize a shared understanding of the researchers of the field of Women Empowerment (WE) research. There are several techniques like citation, co-citation, topic co-occurrence, bibliographic coupling, and overlap visualization used in the scientometric analysis. It helps to understand the in-depth information regarding Women's Empowerment in the business and commerce field. The other experts, **Olawumi & Chan (2018)** presented a scientometric review of global trend and structure of sustainability research of 2094 bibliographic records from the Web of Science database from 1991 to 2016. They have identified such co-author, co-word, co-citation, and clusters. The highest contributions of sustainability research were originated primarily from the United States, China, United Kingdom, and Canada, while the study generated 21 co-citation clusters. **Kumar (2020)** conducted a scientometric analysis of the women empowerment of 391 articles in business and management studies from the Web of Science database between 1985 and 2018. There are numerous techniques like co-citation, co-occurrence, and overlap visualization. Another study conducted by a group of researchers focused on bibliometric analysis of the global performance and development of sustainable city research during 1992 – 2016 in the Web of Science database. This study found that use of visualization tools, such as Science of Science (Sci2), alluvial diagram and Gephi and analysis of keyword plus and author keywords. China was ranked first in natural science research and the USA was also the leading country in social science research (**Wang et al., 2019**). **Velmurugan (2019)** conducted a study on neurology research on the global level as per the scientific publications from 2006 to 2015 in the Web of Science database. The study found a total of 23,335 publications were published in the area of neurology by global researchers, the highest number of publications i.e 3357 were published in 2015, most prolific authors, language-wise distribution of documents, highest productive institutes, and highest productive countries.

3. Objectives of the Study

The main objective of this study is to analyze open-access global research performance on IoT, as reflected in its publications from 2011 to 2020. In specific, the research emphasizes the following aspects:

- To identify open-access global research performance on IoT,
- To examine year-wise the relative growth rate and doubling time of publications on open access IoT research,
- To identify the top most relevant source contribution on IoT research,
- To find out the most prolific authorship pattern of the contribution of articles,

- To visualize country-wise production of documents on IoT research, and
- To examine the language-wise distribution of publications on open access IoT research.

4. Methodology

We have downloaded 10628 publication records from the Web of Science database in the '.txt' format which covers time span of 10 years (2011-2020). The search string used for data extraction is TS= ("IoT" or "Internet of Things"). We selected only the open access publications. We removed some irrelevant record from the collected database manually. We collected dataset on or before January 1, 2020. Data tabulation, analysis, and visualization has been carried out using Bibliometrix Package in RStudio statistical software.

5. Data Analysis and Interpretation

5.1 Document Types

The types of publications in which research work on open access IoT were published during the last 10 years (2011-2020) are listed in Table 1. Out of total publications, 9331 (87.79 %) are research articles, 656 (6.17 %) are reviews, 354 (3.33 %) are editorial material, 147 (1.38%) are article; proceedings paper, 78 (0.73%) are article; early access, 27 (0.25%) are correction. The other forms of publications are very less in number.

Table. 1.Type of Documents in Open Access IoT research

Sl. No.	**Type of Documents**	**Frequency**	**Percentage**
1	Article	9331	87.79
2	Review	656	6.17
3	Editorial Material	354	3.33
4	Article; Proceedings Paper	147	1.38
5	Article; Early Access	78	0.73
6	Correction	27	0.25
7	Review; Early Access	7	0.06
8	Editorial Material; Early Access	6	0.05
9	Letter	5	0.04
10	News Item	3	0.02
11	Book Review	3	0.02
12	Article; Book Chapter	2	0.01

13	Retraction	2	0.01
14	Article; Data Paper	2	0.01
15	Article; Retracted Publication	2	0.01
16	Meeting Abstract	2	0.01
17	Correction; Early Access	1	0.09
Total		10628	100

5.2 Analysis of Relative Growth Rate and Doubling Time in IoT Research

The Relative Growth Rate of research output of the internet of Things (IoT) at the global level is shown in Table 2. It could be seen clearly that the Relative Growth Rates for all sources of Internet of Things (IoT) research output increased from 0.34 (2012) to 0.78 (2017). The study reveals the fact that the Relative Growth Rates started increasing from 0.34 to 1.06. The overall Relative Growth Rate (RGR) calculated in the present study is 0.65 and Doubling Time is 0.95. The Mean Relative Growth Rates for the five years of the two blocks are found to be 0.46 (2011-2015) and 0.84 (2016-2020).

The Mean Doubling Time for publications for the five-year blocks is calculated to be 1.07 (2011-2015), and 0.83 (2016-2020). The highest growth of Doubling Time (DT) 2.03 is observed only in the year 2012. It started decreasing from 2011 to 2012 and the trend of decrease continued till 0.87 in 2015. The remaining years also followed up and down in the case of Doubling Time of publications. The study results validate the fact that when the Relative Growth Rate (RGR) increases, the Doubling Time (DT) decreases.

Table. 2. Relative Growth Rate and Doubling Time of Publications

Year	Number of Records	Cumulative No. of output	W1	W2	R(a) W2 - W1	Mean R(a) (1-2)	Doubling Time Dt (a)	Mean Dt (a)
2011	18	18	2.89	2.89	0			
2012	44	62	3.78	4.12	0.34		2.038235	
2013	95	157	4.55	5.05	0.5	0.46	1.386	1.07
2014	171	328	5.14	5.79	0.65		1.066154	
2015	274	602	5.6	6.4	0.7		0.87721	

			1		9		5	
2016	540	1142	6.29	7.04	0.75	0.84	0.924	0.83
2017	969	2111	6.87	7.65	0.78		0.888462	
2018	1922	4033	7.56	8.3	0.74		0.936486	
2019	2895	6928	7.97	8.84	0.87		0.796552	
2020	3700	10628	8.21	9.27	1.06		0.653774	
Total	10628	26009				0.65		0.95

5.3 Top 20 Journals of Internet of Thing (IoT) Research

The total number of 10628 research publications on open access IoT during study period published in sources. The top 20 journals where most of the open access IoT research articles were published are given in Table 3. IEEE Access is at the top of the list having highest open access publications on IoT (2504), followed by Sensors (1844). The h-index, g-index, and m-index of IEEE Access are 63, 111, and 7.875 respectively and remained at the first position. Sensors stood in the second position having total citation, h-index, g-index, and m-index were 14218, 43, 69, and 3.9001 respectively. It is followed by Electronics. It is lastly followed by Scientific Reports with 48 records, and it stood in the lowest position along with 489 total citation score, and h, g, and m-index score scaled 11, 21, and 1.375 respectively (Figure.1).

Table. 3. Prolific Source of IoT Research Performance

Sl. No.	**Source of Publication**	**NP**	**TC**	**h-index**	**g-index**	**m-index**
1	Ieee Access	2504	24248	63	111	7.875
2	Sensors	1844	14218	43	69	3.9091
3	Electronics	368	965	15	20	2.1429
4	International Journal of Distributed Sensor Networks	366	2545	19	43	1.9
5	Applied Sciences-Basel	318	1080	16	21	2.2857
6	Ieee Internet Of Things Journal	289	8405	39	84	4.875
7	Wireless Communications & Mobile Computing	256	747	14	18	1.75
8	Sustainability	232	1377	18	31	2.5714
9	Energies	154	821	14	23	2
10	Security and	137	790	12	25	1.3333

	Communication Networks					
11	Eurasip Journal on Wireless Communications and Networking	114	900	15	26	1.3636
12	Symmetry-Basel	111	373	8	14	1
13	Mobile Information Systems	98	407	10	16	1
14	Sensors and Materials	80	59	3	4	0.5
15	Journal of Sensors	77	290	10	11	1.25
16	Future Generation Computer Systems-The International Journal of Escience	65	1253	18	33	2
17	Ksii Transactions on Internet and Information Systems	57	89	5	6	0.7143
18	Ieice Transactions on Information and Systems	54	127	6	9	0.75
19	Ieee Transactions on Industrial Informatics	53	1637	18	40	2
20	Scientific Reports	48	489	11	21	1.375

NP= "Number of Publications", TC= "Total Citations"

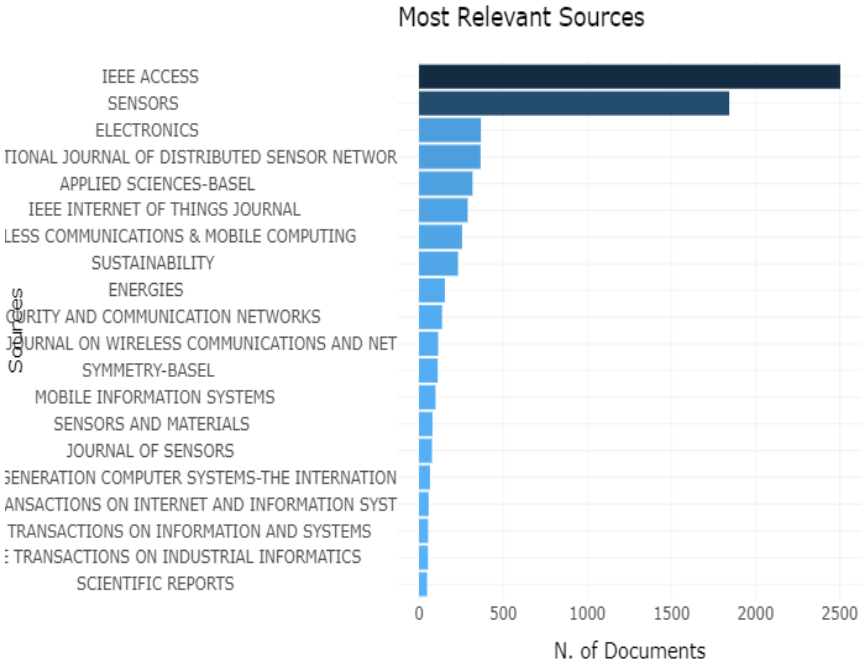

Figure. 1. Most Relevant Sources

5.4 Most Prolific Authors in IoT Research

The top 20 authors who contributed maximum scholarly output on open access Internet of Things (IoT) research at the global level is tabulated (Table 4). Zhang Y has published highest number of publications (72), followed by Kim J 71, Kim S 71, and Park S 50. It is also found that 10 out of 20 prolific authors contributed more than 50 research publications each while other 10 authors contributed less than 45 but more than 38 publications each. The h-index is highest for Zhang Y (13), followed by Liu Y, Rodrigues JJPC and Zhang L (12), Li H (11), Kim J, Lee J, Wang J, Lix, and Wang Y (10). The data set puts the author Zhang Y with 33 g-index in the first position, followed by Lee J, Rodrigues JJPC, and Zhang L with 21 g-index, Liu Y with 20 g-index, Wang J, and Li X with 19 g-index. So far the m-index is concerned, Li H is 1.375, followed by Wang J (1.667), Kim S, and Kim Y (1.443) (Figure. 2).

Table. 4. Most Prolific Authors

Sl. No.	Authors	TP	TC	h-index	g-index	m-index
1	Zhang Y	73	1143	13	33	0

2	Kim J	71	296	10	15	0
3	Kim S	71	193	8	10	1.143
4	Park S	67	237	9	14	0
5	Lee J	60	479	10	21	0
6	Kim H	58	186	8	11	1
7	Liu Y	56	466	12	20	1.333
8	Wang J	56	410	10	19	1.667
9	Kim D	53	187	7	12	0.778
10	Lee S	52	177	6	12	0.857
11	Rodrigues JJPC	45	482	12	21	1.333
12	Li J	44	255	8	14	1
13	Zhang L	44	494	12	21	1.333
14	Li X	43	384	10	19	1.429
15	Li Y	42	252	9	15	1.286
16	Park Jh	42	379	7	18	0.778
17	Wang Y	41	239	10	14	1
18	Kim Y	40	151	8	10	1.143
19	Li H	38	355	11	18	1.375
20	Yang Y	38	257	9	15	1

TP= "Total of Publications", TC= "Total Citations"

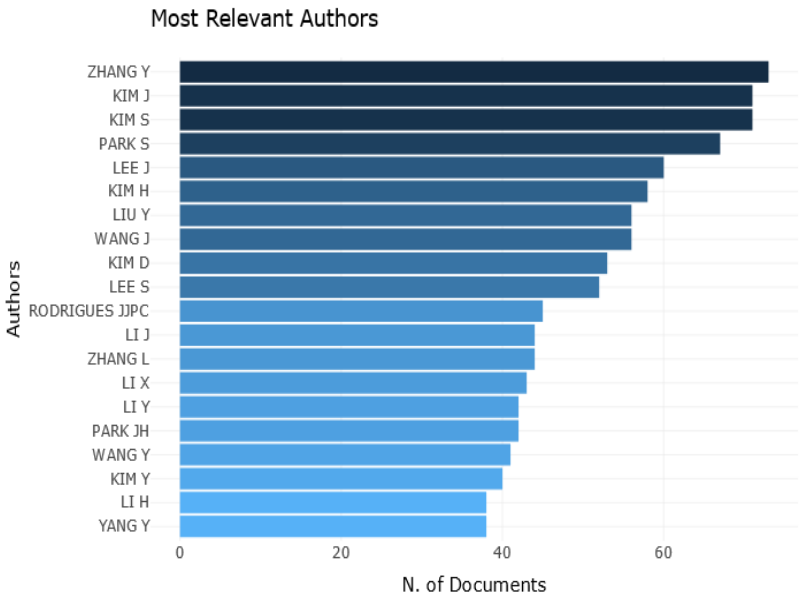

Figure. 2. Most Relevant Authors

5.5 Top 20 Corresponding Authors Country and Publications

The top 20 countries of corresponding authorswith their number of publications, Single-Country Publications (SCP), Multiple Country Publications (MCP), and Multiple Country Publication Ratio (MCP-Ratio) are enlisted in table-5. Here high MCP indicates the higher collaboration with other countries. Among these 20 countries, China is holding the first position with a total of 3092 publications of which 2076 are SCP and 1016 are MCP with an MCP-Ratio of 0.329. Korea is in the second position with a total of 1252 publications of which SCP, MCP, and MCP-Ratio are 902, 350, and 0.28 respectively. Spain and the United Kingdom respectively are the third and fourth corresponding countries in the list with 209 MCP, 515 SCP, MCP-Ratio 0.289 out of 724 articles and 343 SCP, 355 SCP, and MCP 0.491 out of 698 articles. Figure 3 shows the graphical representation of the corresponding authors' country and document publications.

Table. 5. Top 20 Corresponding Authors' Country and Documents

Country	**Articles**	**Frequency**	**SCP**	**MCP**	**MCP-Ratio**
CHINA	3092	0.292	2076	1016	0.329
KOREA	1252	0.118	902	350	0.28
SPAIN	724	0.0684	515	209	0.289
UNITED KINGDOM	698	0.0659	355	343	0.491
USA	682	0.0644	451	231	0.339
ITALY	400	0.0378	258	142	0.355
JAPAN	272	0.0257	206	66	0.243
SAUDI ARABIA	194	0.0183	87	107	0.552
CANADA	175	0.0165	83	92	0.526
AUSTRALIA	171	0.0162	91	80	0.468
PAKISTAN	162	0.0153	50	112	0.691
INDIA	159	0.015	89	70	0.44
BRAZIL	149	0.0141	76	73	0.49
GERMANY	144	0.0136	84	60	0.417
FINLAND	136	0.0128	52	84	0.618
FRANCE	121	0.0114	56	65	0.537
MALAYSIA	117	0.0111	46	71	0.607

BELGIUM	114	0.0108	79	35	0.307
SWEDEN	106	0.01	66	40	0.377
PORTUGAL	95	0.00897	63	32	0.337

SCP= "Single Country Publication", MCP= "Multiple Country Publications"

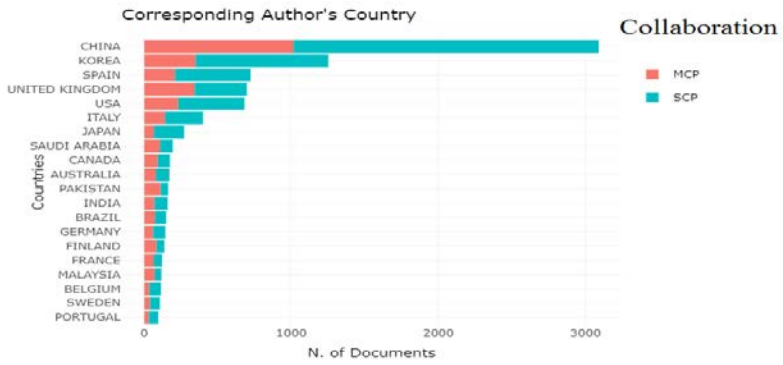

Figure. 3. Corresponding authors' country and documents

5.6 Social structure, Contributions of countries

Figure 4 shows a strong collaboration between the researchers from China and the researchers from rest of the world. Studies show that researchers from China (3092 papers), Korea (1252 papers), Spain (724 papers), United Kingdom (698 papers), and the USA (682 papers) have played a major role in the scientific production of open-access IoT research.

Figure. 4.Word Map Collaboration

5.7 Authors Keywords in IoT Research

Table- 6 and Figure-5 and 6 reveal the greatest preferred keyword used by investigators in their research papers. Among the top 20 keywords, internet of things occurred in 2739 (30%) records, IoT occurred in 1203 (13%) records, internet of things (IoT) occurred in 643 (7%) records, security occurred in 513 (6%) records, and machine learning occurred in 350 (4%) records. Here the authors have shown a visualization of research hotspots with often occurring keywords during the timespan under study using R Stadio (Biblioshiny) software.

Table. 6. Authors Keywords in IoT Research

Rank	Terms	Frequency	Percentage
1	Internet of Things	2739	30%
2	IoT	1203	13%
3	Internet of Things (IoT)	643	7%
4	Security	513	6%
5	Machine Learning	350	4%

6	Edge Computing	340	4%
7	Cloud Computing	339	4%
8	Blockchain	328	4%
9	Wireless Sensor Networks	319	3%
10	Big Data	262	3%
11	Fog Computing	244	3%
12	Internet of	235	3%
13	Privacy	235	3%
14	Sensors	220	2%
15	Authentication	212	2%
16	Smart City	204	2%
17	Deep Learning	195	2%
18	Things	189	2%
19	Energy Efficiency	186	2%
20	5g	177	2%

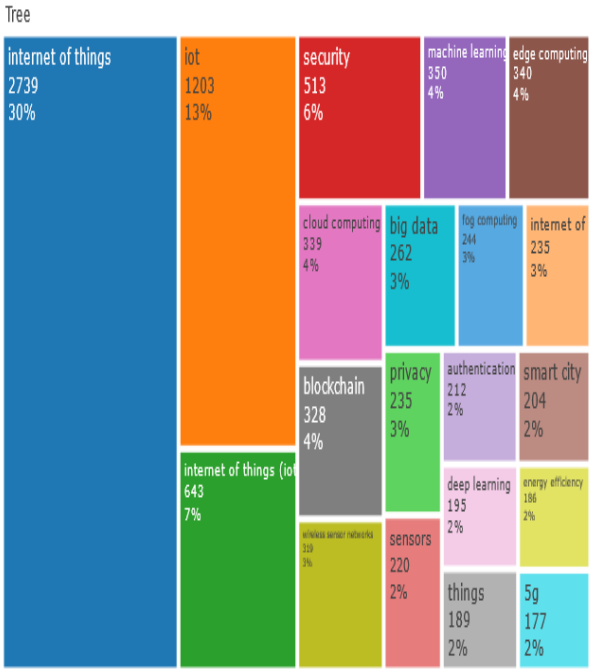

Figure. 5. The Frequency of the Keywords

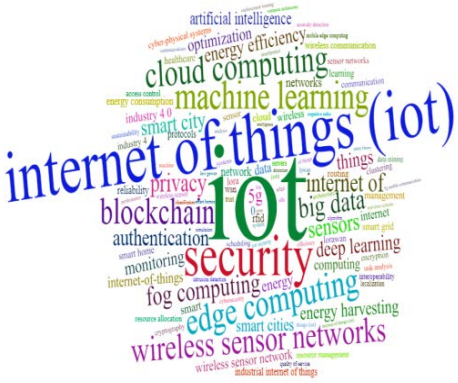

Figure. 6.Authors words cloud

5.8 Conceptual Structure Map and Multiple Correspondence Analyses (MCA)

Figure 7 indicates the conceptual structure map using co-occurrence of words. The words have been replaced by authors' keywords, keyword plus, and terms taken from titles and abstracts. Conceptual structure map has been derived through Multiple Correspondence Analysis (MCA). It is found from this analysis that, cluster 1 has the most keywords. That can draw an inference that most of the investigators carried out their study on that particular domain. It reflects the domain of interest of majority of the researchers across the globe on IoT.

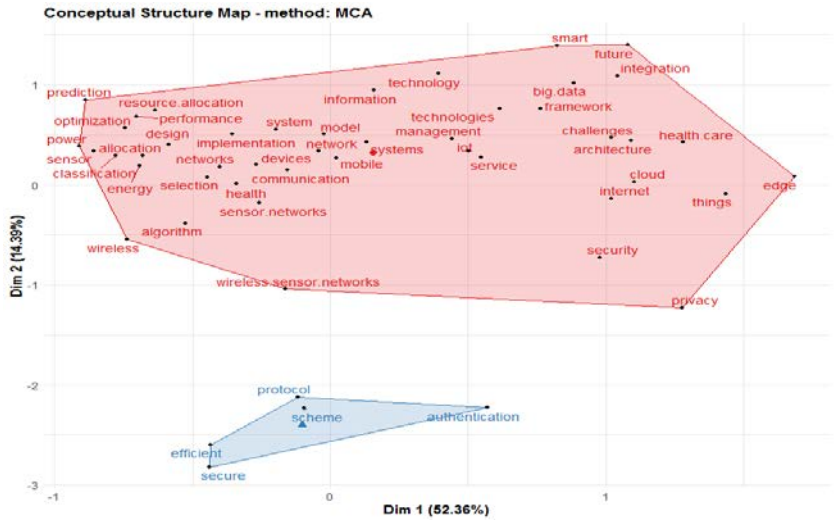

Figure. 7.Conceptual structure Map-Method: MCA

5.9 Intellectual Structure, Historiograph

Gozem (2012), Miorandi (2012), Li sc (2013) Sanchez I (2014), Kamalinejad (2015), Sanchez-iborra (2016), Wang (2017), and Mouradian (2018) were the beginner of new trends at their own time (Figure 8). The directions of the arrows depict the history of change of research trends from the past. Research accomplished by Perera (2014) was about the effects of open access IoT research. Miorandi (2012), Li sc (2013), Yang (2014), Sanchez (2014), and Ghayvat (2015) provided more development on the Internet of Things (IoT). Islam (2015) tried to understand which elements of nature influence more people to locations around the world and whether changes in ecosystems could

alter visitation rates. They believed while Minoli (2017) observed that IoT content is generated by a small number of 'outliers' is correct.

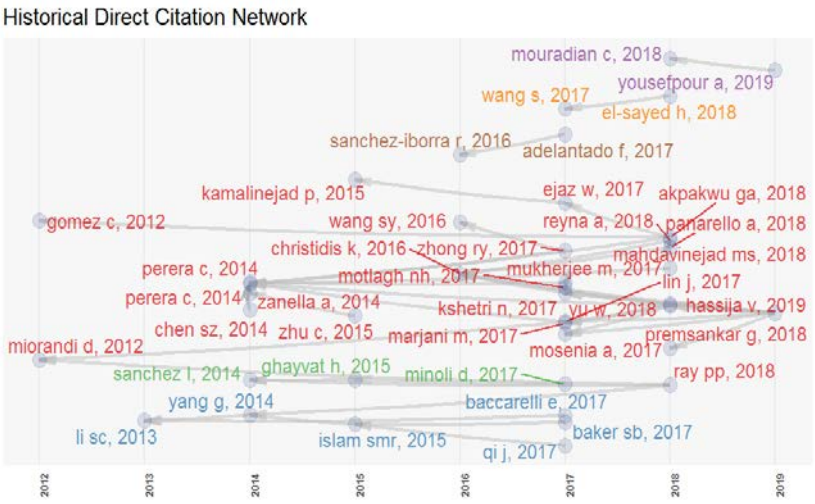

Figure. 8.Historiograph

5.10 Analysis of Language Wise Distribution of Open Access IoT Research

Table 7 shows the language-wise analysis of scholarly publications on open access IoT research. Publications in English language are maximum compare to other. It is accounted for the first position with 10588 (99.62%) records. The data vastly support the truth that no other language is capable to compete with the English language. The Spanish language holds the second position having 20 (0.18) records. The Chinese language contributed 6 (0.05) records, and it occupies the third position. It could be identified that most of the scientists prefer the English language as a medium for their publications to share scholarly information. As we know that English is the medium of research communication as it is broadly recognized around the world as the same is supported in the current study.

Table. 7. Language Wise Distribution of IoT Research

Sl.no	**Language**	**Records**	**%**
1	English	10588	99.62
2	Spanish	20	0.18
3	Chinese	6	0.05
4	Portuguese	5	0.04
5	Afrikaans	4	0.03
6	Russian	2	0.01
7	Turkish	2	0.01
8	Japanese	1	0.009
Total		10628	100

6. Conclusion

A scientometrics assessment about the Internet of Things (IoT) was performed over a data set of 10628 documents published during a period of 10 years (2011–2020) from the Web of Science database. Internet of Things (IoT) represents the integration approach of different subject fields. The function of IoT includes connection of various electronic devices, configure, troubleshoot, data transferring, data storing, secure, manage, interacting through the internet, all communication, and sharing information. The present study reveals an increasing trend towards open access IoT research among researchers. The average relative growth rate was 0.65 and the highest relative growth rates have been registered in the year 2020. The most relevant author was Zhang Y with 73 publications and 1143 citations. The highest number of papers were published from China, Korea, Spain, United Kingdom, the USA, and others during the marked study period. Most of 10588 (99.62%) research publications were published in the English language and only one research publication is published in the Japanese language.

A detailed scientometric analysis of open access Internet of Things (IoT) publications in the global perspective has revealed a clear picture of IoT research trend and its collaborative nature. From this study we can take necessary measures to enhance the research space and pace.

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