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Fog Computing Research: A Scientometric Assessment of Global Publications Output During 2012-18

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Abstract

The present study has examined fog computing global research output, as indexed in Scopus database during 2012-18 on a series of bibliometric measures, such as publications growth rate, global publications share, citation impact, the share of international collaborative papers, distribution of publications by broad subjects. In addition, the study discusses the citation profile of top organizations and authors in fog computing, and the preferred media for research communication and characteristics of highly cited papers. The study finds 1711 global research output registered (68.09%) annual growth rate. 81 countries participated in fog computing research, of which the top 10 countries accounted for 91.23% global publication share and more than 100% of global citation share during 2012-18. China and USA tops the list of top 10 most productive countries in fog computing research with 22.38% and 19.40% global publication share, followed by India (9.70%), Italy (7.36%), Australia (6.14%), etc. USA top the list (17.02% and 2.25%), followed by Australia (15.54% and 2.06%), UK (12.09% and 1.59%), Canada (11.03% and 1.46%), Spain (9.95% and 1.32%), etc. in terms of citation impact per paper and relative citation index. 401 organizations and 457 authors participated in global fog computing research, of which the top 10 organizations and authors contributed (15.02% and 7.48%) global publication share and (42.17% and 12.81%) global citations share during 2012-18. The world contributed (59.75%) share of output in fog computing research in top 20 most productive journals, and 19 of its papers have been rated as highly cited papers each with 100 to 1657 citations per paper, averaging 209.79 citations per paper

KeyTerms: Fog Computing, Edge Computing, Global Publications, Scientometrics, Bibliometrics

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Introduction

With the rise and accretion of smart devices, particularly mobile phones, wearable gadgets and sensors, it brings us to a new era of computing technology known as "internet of things" too many. The "internet of things" includes smart machines interacting with other machines, environments and infrastructures, which results from the massive increase in the volume of digitally generated data. To alleviate the burden of the limited storage capacity of a device, cloud computing is considered a growing paradigm, which provides on-demand storage and other services to the end user. However, despite the numerous applications where cloud helps in accelerating the "internet of things" growth around the physical world, there are some application scenarios still not getting benefits from this emerging computing platform. Some of the cloud computing fundamental problems like unacceptable latency, incapable for location awareness services, lack of mobility support, unnecessary network bandwidth consumption and undefined security issues from the third party and others are reasons for its rejection in some interactive and real-time applications[1].

Fog computing also termed edge computing, can address those problems by providing elastic resources and services to end users at the edge of the network while cloud computing is more about providing resources distributed in the core network. The fog computing, which extends cloud computing to the edge of networks tends to decrease the latency and network congestion, which create scope for new applications and services for billions of connected devices? Fog computing manages a highly distributed and possibly

virtualized environment that provides computing and network services between sensors and cloud data centers. Similar to the cloud, fog provides data, compute, storage, and application services to end-users[2-4]. Fog devices are positioned between cloud and smart devices. Their high-speed Internet connection to the cloud, and physical proximity to users enables real-time applications and location-based services, and mobility support. Cisco promoted fog computing concept in the areas of smart grid, connected vehicles and wireless sensor and actuator networks[4].

Literature Review

There is no quantitative study until today on the bibliometric assessment of global fog computing research output. However, other bibliometric studies are available in the area of internet of things[5], cloud computing[6-7] and other computing research areas such as grid computing[8], mobile computing[9], mobile cloud computing[10], parallel computing[11], pervasive and ubiquitous computing[12], quantum computing[13], supercomputing[14] and computing research in general[15-18].

Objectives

- To study the growth and distribution of global publication and their citation impact
- To ascertain the contribution and impact of top 10 most productive countries and their global profile
- International collaborative profile of top 10 countries
- Scientometric profile of 10 most productive Indian organizations and 10 most productive authors in the subject
- Distribution of Indian publications output by broad subject areas and identification of significant keywords
- Medium of research communication
- Bibliographic characteristics of highly cited papers in the subject

Methodology

The global publication data for the study on fog computing research during 2012-18 was retrieved and downloaded from the Scopus database (http://www.scopus.com). For publications data on global output in the subject, a search strategy was formulated, wherein the keyword such as "fog computing" was used in the "Keyword" and "Title of Paper" tags and limited the resultant search output to time period '2012-18' by using "date range tag". This main search strategy pulled out from the Scopus database leads to 1711 records on global publications on fog computing research. The above described main search strategy was refined by "Country Name Tag" to ascertain and determine research output of top 10 most productive countries one by one. A detailed analysis was further carried out on 1711 Indian publications output data by using the analytical provisions of Scopus database in order to determine the distribution of research data by subject, collaborating countries, author-wise, organization-wise and journal-wise, etc. The citations to publications were also collected from the date of publication till 27 January 2019.

Data Analysis

Publications & Citations Analysis

The fog computing global research output cumulated to a total of 1711 publications during 2012-18. The global annual output on fog computing grew in volume from 2 in 2012 to 1063 publications respectively in 2018.

Table 1: World Publications Output in Fog Computing Research

Publication Year	TP	TC	CPP
2012	2	1752	876
2013	4	447	111.75
2014	12	1385	115.42
2015	45	1724	38.31
2016	128	2642	20.64
2017	457	3286	7.19
2018	1063	1694	1.59
2012-18	1711	12930	7.56

Of the total global publications output (1711) in the field, 55.06% (942 publications) appeared as conference papers, 32.38% (554) as articles, 7.19% (123) as articles in press, 2.05% (35 each) as book chapters and reviews, 0.88% (15) as editorials, 0.18% (3) as books, 0.12 (2) as erratum and 0.06 (1 each) as conference review and short survey.

Most Productive Countries

A total of 81 countries across the world participated in fog computing research and their distribution across contributing countries is skewed of these, 46 countries contributed 1-10 papers each, 10 countries 11-20 papers each, 12 countries 21-50 papers each, 6 countries 51-100 papers each, 5 countries 101-200 papers each and 2 countries contributed 301-383 papers each. The top 10 countries accounted for (91.23%) global publication share and more than 100% of global citation share during 2012-18. The individual global publication share of top 10 countries varied from (4.15% to 22.38%). China and USA top the list of top 10 most productive countries in fog computing research with (22.38%) and (19.40%) global publications share, followed by India (9.70% share), Italy (7.36%), Australia (6.14%), Canada and UK (6.08% each), South Korea (5.61%), Spain (4.32%) and France (4.15%). In terms of citation impact per paper, Australia tops the list (12.69% and 2.25%), followed by Australia (15.54% and 2.06%), UK (12.09% and 1.59%), Canada (11.03% and 1.46%), Spain (9.95% and 1.32%), etc. (Table 2)

Table 2: Global Publication Share of Top 10 Most Productive Countries

S. No.	Country	TP	TC	CPP	HI	ICP	%ICP	RCI	%TP
1	China	383	2138	5.58	25	198	51.70	0.74	22.38
2	USA	332	3649	10.99	30	206	62.05	2.25	19.40
3	India	166	546	3.29	11	44	26.51	0.44	9.70
4	Italy	126	674	5.35	14	52	41.27	0.71	7.36
5	Australia	105	1332	12.69	19	77	73.33	2.06	6.14
6	Canada	104	1147	11.03	17	65	62.50	1.46	6.08
7	UK	104	1249	12.09	19	78	75	1.59	6.08
8	South Korea	96	891	9.28	16	33	34.38	1.23	5.61
9	Spain	74	736	9.95	11	38	51.35	1.32	4.32
10	France	71	474	6.68	10	50	70.42	0.88	4.15
Total		**1561**	**12836**	**8.22**	**24.57**	**841**	**53.88**	**1.28**	**91.23**
World output		**91.23**	**99.27**	**7.56**	--	--	--	--	--

Subject-Wise Distribution of Research Output

The global publications output in fog computing research during 2012-18 spreads across nine sub-fields (as identified in Scopus database classification). Computer science accounts for the highest publications share (90.30%), followed by engineering (43.83%), mathematics (17.83%), and other six broad subjects (from 1.23% to 7.31%) during 2012-18. Computer science recorded the highest citation impact per paper of (7.71), followed by materials science (5.75), engineering (4.33), medicine (3.95) and other five subjects from (0.12 to 3.89) (Table 3).

Table 3: Subject-Wise Breakup of Indian Publications

Broad Subject	TP	TC	CPP	HI	%TP
Computer Science	1545	11909	7.71	44	90.30
Engineering	750	3249	4.33	27	43.83
Mathematics	305	1046	3.43	17	17.83
Decision Science	125	486	3.89	13	7.31
Materials Science	101	581	5.75	13	5.90
Physics & Astronomy	93	227	2.44	8	5.44
Social Sciences	81	10	0.12	336	4.73
Energy	51	70	1.37	4	2.98
Medicine	21	83	3.95	5	1.23

Significant Keywords

54 keywords were identified as significant for the purpose of searching for information on major aspects of research studies on fog computing. Table 4 lists them in the decreasing order of search 'hits' as found in Scopus database search covering the period 2012-18. The number of hits was the largest (1545) in the case of keyword "Fog computing", followed by "Fog" (1114), "Internet of Things" (796), "Cloud computing" (497), "Edge computing" (352), "Distributed computer systems" (270), etc. (Table 4)

Table 4: Significant Keywords on Fog Computing Literature

S. No.	Keyword	Frequency	S. No.	Keyword	Frequency
1	Fog computing	1545	31	Vehicular Ad Hoc Networks	37
2	Fog	1114	32	Intelligent Buildings	33
3	Internet of Things	796	33	Smart Power Grids	33
4	Cloud Computing	497	34	Sensors	29
5	Edge Computing	352	35	Web Services	28
6	Distributed Computer Systems	270	36	Vehicle to Vehicle Communications	27
7	Digital Storage	215	37	Vehicular Networks	27
8	Network Architecture	215	38	Intelligent Transport Systems	25
9	Computer Architecture	209	39	Data Centers	24
10	Data Handling	164	40	Mobile Applications	24
11	Quality of Service	148	41	Traffic Congestion	24
12	Big Data	146	42	Economic & Social Effects	23
13	Energy Utilization	119	43	Energy Conservation	23
14	Energy Utilization	119	44	Game Theory	23
15	Energy Efficiency	115	45	Radio Access Networks	23
16	Green Computing	110	46	Social Networks (Online)	21
17	Resource Allocations	100	47	Cloud Data Centers	20
18	Smart City	99	48	Cluster Computing	20
19	Computing Architecture	75	49	Energy Efficient	20
20	Mobile Telecommunication Systems	75	50	Genetic Algorithms	20
21	Mobile Cloud Computing	74	51	Learning Algorithms	20
22	Cryptography	73	52	Smart Phones	20
23	Embedded Systems	73	53	Cloudlet	19

Most Productive Indian Organizations

A total of 401 organizations participated in fog computing research, of which 258 contributed 1-5 papers each, 92 organizations 6-10 papers each, 41 organizations 11-20 papers each and 10 organizations 21-50 papers each.

Top 10 most productive organizations contributed 21 to 45 publications each, together they contributed (15.02%) share (257 publications), and cumulated 5453 citations (42.17% share) during 2012-18. Two organizations registered their publications output above the group average of 25.7: Beijing University of Posts & Telecommunications, China (45 papers) and Shanghai Jiao Tong University, China (28 papers); Five organizations registered impact of their output and relative citation index above the group average of 21.22 citations per publication and 2.81: CISCO Systems, USA (126.19 and 16.69), Deakin University, Australia (35.04 and 4.64), University of Melbourne, Australia (23.10 and 3.05), and Kyung Hee University, South Korea (22.52 and 2.98).

Table 5: Scientometric Profile of 10 Global Organizations

S. No	Organization	2012-18					
		TP	TC	CPP	ICP	%ICP	RCI
1	Beijing University of Posts & Telecommunications, China	45	275	6.11	18	40	0.81
2	Shanghai Jiao Tong University, China	28	64	2.29	18	64.3	0.30
3	Kyung Hee University, South Korea	25	563	22.52	9	36	2.98
4	University of Science & Technology, Beijing, China	25	203	8.12	10	40	1.07
5	Deakin University, Australia	24	841	35.04	19	79.2	4.64
6	Beijing Jiaotong University, China	24	95	3.96	12	50	0.52
7	Universitat Politecnica de Catalunya, Spain	23	160	6.96	12	52.2	0.92
8	Xidian University, China	21	117	5.57	12	57.1	0.74
9	University of Melbourne, Australia	21	485	23.10	13	61.9	3.05
10	CISCO Systems, USA	21	2650	126.19	12	57.1	16.69
Total of 20 organizations		**257**	**5453**	**21.22**	**135**	**52.5**	**2.81**
Total of India		**1711**	**12930**	**7.56**	**--**	**--**	**--**
Share of 10 organizations in India's output		**15.02**	**42.17**	**--**	**--**	**--**	**--**

Most Productive Indian Authors

A total of 457 authors contributed to fog computing research in India, of which 376 authors contributed 1-5 papers each, 67 authors 6-10 papers each and 14 authors 11-14 papers each during 1993-18. Top 10 most productive Indian authors in fog computing research contributed 12 to 14 publications each,

Table 6: Scientometric Profile of 10 Indian Authors

S. No	Author	Affiliation	2012-18					
			TP	TC	CPP	ICP	% ICP	RCI
1	P. Liljeberg	University of Turku, Finland	14	233	16.64	13	92.86	2.20
2	T. Wang	Huaqiao University, China	14	107	7.64	6	42.86	1.01
3	M. Aazam	Kyung Hee University, South Korea	13	436	33.54	9	69.23	4.44
4	R. Buyya	University of Melbourne, Australia	13	358	27.54	9	69.23	3.64
5	A.M. Rahmani	University of Tur ku, Finland	13	233	17.92	12	92.31	2.37
6	H.Tenhunen	University of Turku, Finland	13	132	10.15	12	92.31	1.34
7	J. Al-Jaroodi	Robert Morris University, USA	12	37	3.08	9	75	0.41
8	Z. Han	University of Houston, USA	12	56	4.67	8	66.67	0.62
9	X. Masip-Bruin	Universitat Politecnica de Catalunya, Spain	12	27	2.25	6	50	0.30
10	N. Mahamed	Middleware Technologies Lab.; Pittsburg, USA	12	37	3.08	9	75	0.41
Total			**128**	**1656**	**12.94**	**93**	**72.66**	**1.71**
World Total			**1711**	**12930**	**7.56**	**--**	**--**	**--**
Share of top 10 organizations in world total			**7.48**	**12.81**	**--**	**--**	**--**	**--**

cumulated 128 papers (7.48% share), cumulated 1656 citations (12.81% share) during the period. Table 6 presents a scientometric profile of 10 authors.

Medium of Research Communication

Of the total global output contributed in fog computing, 49.62% (849) appeared in conference proceedings, 41.96% (718) in journals, 5.08% (87) in book series, 2.10% (36) as books, and 1.23% (21) as trade publications. Of the 189 journals which published 718 papers,165 reported 1-5 papers each, 13 journals 6-10 papers each, 8 journals 11-50 papers each and 3 journals 51-79 papers each. The top 20 most productive journals reported 59.75% share of the total journal papers in fog computing during 2012-18. The top ranking journal (with 79 papers) was IEEE Access, followed by IEEE Internet of Things Journal (63 papers), Future Generation Computer Systems (51 papers), Wireless Communications & Mobile Computing (37 papers), IEEE Transactions on Industrial Informatics (29 papers each), etc. during 2012-18 (Table 7).

Table 7: Top 20 Most Productive Journals on Fog Computing

S. No.	Journal	Fre quency of Occurrence
1	IEEE Access	79
2	IEEE Internet of Things Journal	63
3	Future Generation Computer Systems	51
4	Wireless Communications & Mobile Computing	37
5	IEEE Transactions on Industrial Informatics	29
6	Sensors Switzerland	27
7	IEEE Communication Magazine	25
8	Concurrency Computation	15
9	Journal of Supercomputing	12
10	International Journal of Engineering & Technology UAE	11
11	Peer to Peer Networking & Applications	11
12	China Communications	9
13	IEEE Internet Computing	9
14	Journal of Ambient Intelligence &Humanized Computing	9
15	IEEE Journal on Select Areas in Communication	8
16	IEEE Network	8
17	IEEE Communication Survey & Tutorials	7
18	IEEE Transactions in Vehicle Technology	7
19	Enterprise Information Systems	6
20	Journal of Parallel & Distributing Computing	6
Total		**429**
Global Total of Journals		**718**
Share of top 20 journals in global output		**59.75**

Highly Cited Papers

Of the total global output in fog computing research (1711 publications), only 19 papers (1.11% share) received 100 to 1657 citations per paper (3986 citations) since their publication, which averaged 209.79 citations per paper. The distribution of 19 highly cited papers by citations is skewed. 13 papers accumulated citations in the range 100 to 199 per paper, 5 papers in the citation range 296-346 and 1 paper received 1657 citations. Of the 19 highly cited papers, 7 resulted from organizations participating in research in their stand-alone capacity (non-collaborative papers) and 12 from two or more organizations participating in their capacity as collaborators (4 national collaborative and 8 international collaborative papers). Among highly cited papers, the organizations from USA accounted for the largest participation (with 9 papers), followed by Australia (4 papers), China and UK (3 papers each), Canada, South Korea and Spain (2 papers each), France, Germany, Hong Kong, Italy, Qatar, Saudi Arabia and Singapore (1 paper each). The 19 highly cited papers resulted from the participation of 68 authors from 39 organizations. The leading global organizations participating in highly cited papers were: CISCO Systems, USA (5 papers), Deakin University, Australia (3 papers) and 1 paper each by other organizations. Of the 19 highly cited papers, 12 were published as a conference paper, 5 as articles and 2 as reviews. These 8 out of 19 highly cited papers appeared across 8 journals, of which 1 paper each were published in Computer, Computer Communication Review, IEEE Communication Survey & Tutorials, IEEE Internet of Things Journal, IEEE Network, IEEE Transactions on Vehicular Technology, Journal of Supercomputing and Studies in Computational Intelligence.

Conclusion

The study has attempted to provide a quantitative and qualitative description of R&D trends in global fog computing research. The bibliometric analysis is based on data sourced from Scopus international database covering the period 2012-18. The world contributed a total of 1711 publications by 81 countries in 7 years, registered (68.09%) annual growth and averaged (167.27%) citations per paper. The analysis reveals that China and USA are the world leaders in fog computing research with global publication share (22.38% and 19.40%), India (9.70%), Italy (7.36%), Australia (6.14%), etc. Top 10 most productive countries together contributed (91.23%) share to global publications output. In terms of citation impact per paper and relative citation index, USA tops the list (17.02% and 2.25%), followed by 9 Australia (15.54% and 2.06%), UK (12.09% and 1.59%), Canada (11.03% and 1.46%), Spain (9.95% and 1.32%), etc.

Computer science is the most popular and major area of research in the subject under study (with 90.30% global share), followed by engineering (43.83%), mathematics (17.83%), and other six broad subjects (from 1.23% to 7.31%) during 2012-18. Computer science recorded the highest citation impact of (7.71%) per paper, followed by materials science (5.75%), engineering (4.33%), medicine (3.95%) and other 5 subjects from (0.12 to 3.89.) 401 organizations and 457 authors participated in global fog computing research, of which the top 10 organizations and authors contributed (15.02% and 7.48%) global publication share and (42.17% and 12.81%) global citations share during 2012-18. The leading most productive organizations were: Beijing University of Posts & Telecommunications, China (45 papers) and Shanghai Jiao Tong University, China (28 papers). The organizations leading in terms of their citation impact and relative citation index were: CISCO Systems, USA (126.19% and 16.69%), Deakin University, Australia (35.04% and 4.64%), University of Melbourne, Australia (23.10% and 3.05%) and Kyung Hee University, South Korea (22.52% and 2.98%).

References

1. Kumar, K. (2017). Fog computing: The essential catalyst for optimizing the true potential of cloud-based internet of things. *International Journal of Applied Research on Information Technology and Computing*, 8(3), 247-62.
2. Yi, S., Li, C. & Li, Q. (2015). A survey of fog computing: Concepts, applications and issues. ACM Workshop on Mobile Big Data, Mobidata; Hangzhou Jinxi HotelHangzhou; China; 21 June 2015 through; Code 116861, 22 June 2015, 37-42.
3. Dastjerdi, A.V., et al. (2016). Internet of things: Principles and paradigms. In Fog Computing: Principles, architectures, and applications, 11 May 2016, 61-75.

4. Stojmenovic, I. & Wen, S. (2014). The fog computing paradigm: Scenarios and security issues. Federated conference on computer science and information systems, Fed CSIS 2014; Warsaw; Poland; 7 September 2014 through 10 September 2014; Category number CFP1485N-ART; Code 108896. 21 October 2014, Article number 6932989, 1-8.
5. Gupta, B.M., Dhawan, S.M. & Gupta, R. (2015). Internet of things: A scientometric assessment of global output, 2005-14. *Journal of Scientometric Research*, 4, 104-14.
6. Gupta, B.M., Singh, N. & Gupta, R. (2015). Indian cloud computing research: A scientometric Assessment of publications output during 2004-13. *SRELS Journal of Information Management*, October, 52(5), 315-326.
7. Gupta, B.M., Singh, N. & Gupta, R. (2015). International cloud computing literature: A scientometric analysis for 2004-13. *Information Studies,* 21(2-3), 111-131.
8. Gupta, B.M., et al. (2018). Grid Computing Research from India: A Bibliometric Assessment of Publications during 2008-2017. *International Journal of Information Dissemination and Technology*, 8(4), 190-195.
9. Dhawan, S.M., Gupta, B.M. & Gupta, R. (2017). Mobile computing: A scientometric assessment of global publications output. *Annals of Library & Information Studies,* 64(3), 172-180.
10. Gupta, B.M., Dhawan, S.M. & Gupta, R. (2017). Mobile cloud computing: A scientometric assessment of global publications output during 2007-16. *Journal of Scientometric Research*, 6(3), 186-194.
11. Gupta, B.M. & Dhawan, S.M. (2019). Parallel computing research in India: A scientometric assessment of Indian publications output during 1998-2017. *COLLNET Journal of Scientometrics & Information Management,* 13(1).
12. Dhawan, S.M., Gupta, B.M. & Gupta, R. (2016). Global pervasive and ubiquitous computing 2005-14. *Annals of Library and Information Studies,* 63(2), 117-25.
13. Dhawan, S.M., Gupta, B.M. & Bhusan, S. (2018). Global publications output on quantum computing: A scientometric assessment during 2007-16. *Emerging Science Journal*, 2(4), 208-237.
14. Dhawan, S.M., Gupta, B.M. & Gupta, R. (2018). Supercomputing: A scientometric assessment of global publications output during 2007-16. *COLLNET Journal of Scientometrics & Information Management*, 12(2), 1-17.
15. Gupta, B.M., Bala, A. & Sharma, N. (2011). Ranking of Indian Institutions contributing to computer science Research, 1999-2008. *DESIDOC Journal of Library & Information Technology*, 31(6), 460-68.
16. Gupta, B.M. & Dhawan, S.M. (2017). Highly cited publications output by India in computer science 1996-2015: A scientometric assessment. *Journal of Scientometric Research,* 6(2), 74-85.
17. Gupta, B.M., Kshitij, A. & Singh, Y. (2010). Indian computer science research output during 1999-2008: Qualitative analysis. *DESIDOC Journal of Library and Information Technology,* 30(6), 39-54.
18. Gupta, B.M., Kshitiji, A. & Verma, C. (2011). Mapping of Indian computer science research output, 1999-2008. *Scientometrics*, 86(2), 261-83.