

Mobile Cloud Computing: A Scientometric Assessment of Global Publications Output during 2007-16

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ABSTRACT

The paper examines 3779 global publications on mobile cloud computing research, as covered in Scopus database during 2007-16, experiencing an annual average growth rate of 139.6% and qualitative impact averaged to 4.22 citations per paper. The top 10 most productive countries individually contributed global share from 2.91% to 22.41%, with largest global publication share coming from China (22.41%), followed by USA (19.32%), etc. Together, the 10 most productive countries accounted for 85.74% share of global publication output during 2007-16. Five out of 10 countries have scored relative citation index above the world average of 1: Malaysia (2.41), USA (1.87), U.K. (1.79), Canada (1.43) and Italy (1.16) during 2007-16. The international collaborative publications share of top 10 most productive countries varied from 9.74% to 67.19% in mobile cloud computing research during 2007-16. Computer Science, among subjects, contributed the largest publication share (85.79%), followed by engineering (28.37%), mathematics and social sciences (10.64% and 5.58%) etc. during 2007-16. The top 20 most productive organizations and authors together contributed 18.92% and 9.98% respectively as their share of global publication output and 37.07% and 24.28% respectively as their share of global citation output during 2007-16. Among the total journal output of 5673 papers, the top 20 journals contributed 30.01% share to the global journal output during 2007-16. Of the total mobile computing research, the top 15 highly cited publications registered citations from 99 to 848 and they together received 3834 citations, with 255.60 citations per paper. These 15 highly cited papers involved the participation of 26 authors and 27 organizations. These 15 highly cited papers were published in 8 journals, of which 4 papers were published in *IEEE Communication Surveys andTutorials*, 2 papers in *Mobile Networks andApplications*, and 1 paper each in other journals.

Keywords: Mobile cloud computing, Mobile research, Cloud computing, Global publications, Scientometrics, Bibliometrics.

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INTRODUCTION

Cloud computing can be defined as the aggregation of computing services as a utility such as software as a service as you go computing.^[1,2,3] In cloud computing the applications are delivered as a service over the internet and the required hardware and systems software that are located in remote data centers provide application services.^[2,3] Also called as “on demand computing”, “utility computing” or “pay as you go computing”, the concept underlying cloud computing is to dispense with the need to own a local computation infrastructure, and instead

outsource it as a remote utility from a remote data/resource service provider.^[3]

The basic models of cloud computing are: Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS). Infrastructure as a Service (IaaS): It provides the required infrastructure for efficient technology, data centers, servers, memory, network, and other hardware for expected IT pedestal to cloud service customers. Examples are Amazon’s Elastic Computing Cloud (EC2), Cisco Unified Service delivery and Flexi scale. Platform as a Service (PaaS): This provides a development environment for applications, using the Internet, operating system and associated services are provided and users need not worry to download or install applications on their computers; for instance, Google Apps Engine, Amazon

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Web Services, and Microsoft Azure. Software as a Service (SaaS) is a software distribution model, the service provider makes applications ready to customers over the internet and it supports Web Services and service-oriented architecture (SOA). Examples include Salesforce.com and IBM Lotus Live. Anything as a Service (XaaS): This refers to the diverse models of information technology-based on-demand services that can be delivered via the cloud computing platform.^[4]

With an explosive growth in the mobile applications coupled with the emerging cloud computing concept, the Mobile Cloud Computing (MCC) has become a potential technology for the mobile service users. MCC integrates the technology of cloud computing with the mobile environment and that this kind of integration has become the part of a major discussion trends in the IT world since 2009. The ABI Research predicts that the number of mobile cloud computing subscribers is expected to grow from 42.8 million (1.1% of total mobile users) in 2008 to 998 million (19% of total mobile users) in 2014. According to the recent survey conducted by the International Data Corporation, most of IT Executives and CEOs are not interested in adopting such services given the drawbacks associated with mobile cloud computing technology (e.g., battery life, storage, and bandwidth), environment (e.g., heterogeneity, scalability, and availability), and security (e.g., reliability and privacy). In spite of ongoing efforts to overcome these pitfalls, the challenges continue to persist in the security policies of mobile cloud computing.^[5] Mobile applications are gaining increasing share in the global mobile market. The cloud computing mobile applications fall in the area of commerce, learning, healthcare, gaming, etc. In addition, a cloud becomes a useful tool to help mobile users share photos and video clips efficiently and tags their friends in popular social networks. A cloud becomes a most effective tool when mobile users require searching services (e.g. searching information, locations, images, voices and video clips).^[6]

Literature Review

Only one study is available, which quantitatively analyze global literature on mobile cloud computing. Ibukun and Daramola^[7] provided a credible intellectual guide for upcoming researchers in mobile cloud computing (MCC) to help them identify areas in MCC research where they can make the most impact from 2002-2014. The study reveals that privacy, security, and trust in MCC are the least researched, whereas issues of architecture, context awareness and data management have been averagely researched, while issues on operations, end users, service, and applications have received a lot of attention.

However, few scientometric studies are available in the area of cloud computing and mobile related research. Amongst cloud computing research studies, Yuanyuan, Lu, Wang and Xing^[8] quantitatively reviewed the progress in global cloud

computing research with the related literature during 2007–2013 from the databases of Science Citation Index Expanded (SCI-E), Conference Proceedings Citation Index–Science (CPCI-S), and IEEEExplore. By investigating the characteristics of publications such as keywords, output, geographic distribution, and affiliation, the authors draw some valuable conclusions to guide the further research. Gupta, Singh, and Gupta.^[9] And Gupta and Gupta.^[10] examined 21397 and 1206 global and Indian publications in cloud computing, as covered in Scopus database during 2004–13, with a view to studying the growth of research output and its distribution by type of publication, contribution and citation impact of top most productive countries, international collaboration share and the extent of inter-country collaborative linkages, the distribution of research output by broad subject areas and identify the important subject keywords to understand trends in research, the publication productivity and citation impact of most productive institutions and authors, leading media of communication and the characteristics of highly cited papers. Amongst mobile related studies, bibliometric studies have conducted in the past on overall mobile research.^[11] mobile computing.^[12,13,14] mobile learning.^[15] mobile banking.^[16] and mobile payment.^[17]

OBJECTIVES

The main objectives of this study are to study the performance of mobile cloud computing research during 2007–16, based on publications output covered in Scopus database. In particular, the study focuses on the following objectives:

- To study the growth of world research output in mobile cloud computing research and its citation impact;
- To study the international collaboration share of top 10 most productive countries;
- To study the global research output by broad subject areas and the dynamics of its growth and decline;
- To study the trends in sub-fields by identifying significant keywords;
- To study the publication productivity and citation impact of top 20 most productive organizations and authors;
- To study the modes of communication in research; and
- To study the characteristics of top 15 highly cited papers.

METHODOLOGY

The study retrieved and downloaded 10-year publication data of the world output in mobile cloud computing research from the Scopus database (<http://www.scopus.com>) covering the period 2007–16. Keywords, such as “mobile cloud computing” or “m-cloud computing” or “mcloud computing” were incor-

porated in the search string and qualified these keywords with “keyword tag”, “Article Title tag”, and in addition incorporated in this search string the period ‘2007-16’ within “date range tag”. Finally, this search string was applied for searching global publication data on mobile cloud computing. The search string was subsequently refined using analytical commands of Scopus database by “subject area tag”, “country tag”, “source title tag”, “journal title name” and “affiliation tag”, to get data/information on the distribution of publications output by subject, collaborating countries, author-wise, organization-wise and journal-wise, etc. For citation data, citations to publications were also collected from date of publication till 29 December 2016. The publications data was analyzed across a few select raw (number of papers and collaborative papers, citation per paper, etc.) and relative bibliometric indicators (such as activity index and relative citation index) with a view to understand the research activity in mobile cloud computing. We have used here complete counting method, where all authors or organizations to multi-authored papers have received equal credit in data counting and analysis. All types of documents have been used in this study.

((KEY (Mobile cloud computing or M-cloud computing or Mcloud computing) AND PUBYEAR > 2006 AND PUBYEAR < 2017) or (TITLE (Mobile cloud computing or M-cloud computing or Mcloud computing) AND PUBYEAR > 2006 AND PUBYEAR < 2017))

Analysis

The total research output of the world in field of mobile cloud computing cumulated to 3779 publications in 10 years during 2007-16. The annual output of the world in mobile computing research increased from 2 in the year 2007 to 752 publications in the year 2016, registering 139.60% growth per annum. The cumulative world output in mobile cloud computing in 5 years 2007-11 increased from 434 to 3345 publications during succeeding 5-year period 2012-16, registering 670.74% quinquennial growth. Of the total global publications output, 83.09% (28784) was published as conference papers, 15.35% (5316) articles, 0.60% (207) as reviews, 0.44% (154) articles in press, 0.20% (71) as book chapters and the rest as conference reviews, editorials, short surveys, notes, letters and books. The citation impact of global publications on mobile cloud computing research averaged to 4.22 citations per publication (CPP) during 2007-16; five-yearly impact averaged to 12.49 CPP for the period 2007-11 which declined to 3.15 CPP in the succeeding five-year 2012-16 Table 1.

Top 10 Most Productive Countries in Mobile Cloud Computing

The global research output in the field of mobile cloud computing had originated from as many as 96 countries in the

Table 1: World Output in Mobile Cloud Computing Research, 2007-16.

Publication Period	World		
	TP	TC	CPP
2007	2	19	9.50
2008	5	3	0.60
2009	35	1652	47.20
2010	132	1799	13.63
2011	260	1948	7.49
2012	361	1972	5.46
2013	546	4136	7.58
2014	763	2454	3.22
2015	923	1754	1.90
2016	752	213	0.28
2007-11	434	5421	12.49
2012-16	3345	10529	3.15
2007-16	3779	15950	4.22

TP=Total Papers; TC=Total Citations; CPP=Citations Per Paper

world during 2007-16. Top 10 most productive countries in mobile cloud computing research had contributed 105 to 847 publications each during 2007-16 Table 2. Of the 96 countries, 47 contributed 1-10 papers each, 30 countries 11-50 papers each, 8 countries 51-100 papers each and 11 countries 106-847 papers each. Top 10 most productive countries in mobile cloud computing research accounted for 85.74% global publication share during 2007-16. Their five-yearly output accounted for 88.94% global publication share during 2007-11 which declined to 85.32% during succeeding 5-year period 2012-16. Each of top 10 countries accounted for 2.91% to 22.41% global publication share during 2007-16, with China accounting for the highest publication share (22.41%), followed by USA (19.32%), India (9.50%), South Korea (7.65%), Canada (5.85%), Taiwan (5.24%), U.K. (5.11%), Germany (4.18%), Italy (3.60%) and Malaysia (2.91%) during 2007-17. The global publication shares in five years increased by 5.79% in India, followed by 3.49% in Canada, 1.99% in Malaysia, 0.59% in China and 0.27% in U.K., as against decrease by 6.03% in USA, 4.38% in Germany, 2.93% in Taiwan, 2.03% in South Korea and 0.36% in Italy from 2007-11 to 2012-16. Five of top 10 countries scored relative citation index above the world average *i.e.* more than 1: Malaysia (2.41), USA (1.87), U.K. (1.79), Canada (1.43) and Italy (1.16) during 2007-16.

International Collaboration

The international collaborative share of top 10 countries in mobile cloud computing in their respective national output varied from 9.74% to 67.19%, with highest share coming from U.K. (67.19%), followed by Canada (52.04%), Malaysia (46.36%), Italy (44.85%), Germany (42.41%), USA (36.58%),

Table 2: Global Publication Share of Top 10 Most Productive Countries in Mobile Cloud Computing during 2007-16.

S.No	Name of the Country	Number of Papers			Share of Papers			TC	CPP	HI	ICP	%ICP	RCI
1	China	95	752	847	21.89	22.48	22.41	3453	4.08	28	268	31.64	0.97
2	USA	107	623	730	24.65	18.62	19.32	5774	7.91	34	267	36.58	1.87
3	India	19	340	359	4.38	10.16	9.50	319	0.89	8	35	9.75	0.21
4	South Korea	41	248	289	9.45	7.41	7.65	1025	3.55	16	52	17.99	0.84
5	Canada	12	209	221	2.76	6.25	5.85	1338	6.05	20	115	52.04	1.43
6	Taiwan	34	164	198	7.83	4.90	5.24	559	2.82	11	35	17.68	0.67
7	U.K.	21	171	192	4.84	5.11	5.08	1449	7.55	14	129	67.19	1.79
8	Germany	35	123	158	8.06	3.68	4.18	527	3.34	11	67	42.41	0.79
9	Italy	17	119	136	3.92	3.56	3.60	664	4.88	13	61	44.85	1.16
10	Malaysia	5	105	110	1.15	3.14	2.91	1121	10.19	18	51	46.36	2.41
	Total	386	2854	3240									
	World	434	3345	3779				15950					
	Share of 10 Countries in World Total	88.94	85.32	85.74									

TP=Total Papers; TC=Total Citations; CPP=Citations Per Paper; HI=h-index; ICP=International Collaborative Papers; RCI=Relative Citation Index

Table 3: Subject-Wise Breakup of Global Publications in Mobile Cloud Computing during 2007-16.

S.No	Subject*	Number of Papers (TP)			Activity Index		TC	CPP	%TP
		2007-11	2012-16	2007-16	2007-11	2012-16	2007-16	2007-16	2007-16
1	Computer Science	390	2852	3242	104.75	99.38	13528	4.17	85.79
2	Engineering	82	990	1072	66.60	104.33	4564	4.26	28.37
3	Mathematics	51	351	402	110.47	98.64	1412	3.51	10.64
4	Social Science	38	173	211	156.82	92.63	513	2.43	5.58
5	Decision Science	6	107	113	46.23	106.98	278	2.46	2.99
6	Medicine	7	86	93	65.54	104.47	310	3.33	2.46
7	Business, accounting and management	11	76	87	110.09	98.69	143	1.64	2.30
8	Physics and astronomy	2	60	62	28.09	109.33	197	3.18	1.64
9	Materials science	4	41	45	77.40	102.93	65	1.44	1.19
	World Output	434	3345	3779	100.00	100.00			

There is overlapping of literature covered under various subjects

TP=Total Papers; TC=Total Citations; CPP=Citations Per Paper

South Korea (17.99%), Taiwan (17.68%) and India (9.75%) during 2007-16.

Subject-Wise Distribution of Research Output

The global mobile cloud computing output published during 2007-16 is distributed across nine sub-fields (as identified in Scopus database classification), with computer science accounting for the highest publications share (85.79%), followed by engineering (28.37%), mathematics (10.64%), social sciences (5.58%), decision science, medicine, and business, accounting and management (from 2.30% to 2.99%), physics and astronomy and materials science (from 1.19% to 1.64%) during 2007-16.

The activity index, which computes change in research activity in a discipline over time 2007-11 to 2012-16 (world average activity index of a given subject is taken as 100), witnessed increase in engineering (from 66.0 to 104.33), decision science (from 46.23 to 106.98), medicine (from 65.54 to 104.47), physics and astronomy (from 28.09 to 109.33) and materials science (from 77.40 to 102.93), as against decline of research activity in computer science (from 104.75 to 99.38), mathematics (from 110.47 to 98.64), Social science (from 156.82 to 92.63) and business, accounting and management (from 110.09 to 98.69) from 2007-11 to 2012-16 Table 3.

Table 4: Scientometric Profile of Top 20 Most Productive Global Organizations in Mobile Cloud Computing Research in India during 2007-16.

S.No	Name of the Organization	TP	TC	CPP	HI	ICP	%ICP	RCI
1	Beijing University of Post and Telecommunications, China	89	331	3.72	7	8	8.99	0.88
2	University of Malaya, Malaysia	54	935	17.31	17	35	64.81	4.10
3	Tsinghua University, China	53	364	6.87	9	26	49.06	1.63
4	Huazhong University of Science and Technology, China	49	455	9.29	8	36	73.47	2.20
5	Kyung Hee University, South Korea	40	240	6.00	5	12	30.00	1.42
6	King Saud University, Saudi Arabia	39	210	5.38	7	24	61.54	1.28
7	Xidian University, China	38	116	3.05	7	18	47.37	0.72
8	University of British Columbia, Canada	37	338	9.14	9	29	78.38	2.16
9	Arizona State University, USA	36	392	10.89	11	16	44.44	2.58
10	University of Saskatchewan, Canada	33	96	2.91	5	2	6.06	0.69
11	Aalto University, Finland	32	97	3.03	6	18	56.25	0.72
12	University of Ottawa, Canada	29	130	4.48	5	21	72.41	1.06
13	Sapienza University of Rome, Italy	25	250	10.00	7	13	52.00	2.37
14	Korea University, South Korea	24	104	4.33	6	1	4.17	1.03
15	Microsoft Research, USA	24	1015	42.29	6	7	29.17	10.02
16	Wuhan University, China	24	42	1.75	4	5	20.83	0.41
17	University of Melbourne, Australia	23	535	23.26	9	18	78.26	5.51
18	Electronics and Telecommunication Research Institute, South Korea	22	57	2.59	5	0	0.00	0.61
19	University Politehnica of Bucharest, Romania	22	18	0.82	2	7	31.82	0.19
20	Georgia Institute of Technology, USA	22	188	8.55	6	3	13.64	2.02
	Total of 20 organizations	715	5913	8.27	7.05	299	41.82	
	Total of World	3779	15950	4.22				
	Share of top 20 organizations in World total output	18.92	37.07					

TP=Total Papers; TC=Total Citations; CPP=Citations Per Paper; HI=h-index; ICP=International Collaborative Papers; RCI=Relative Citation Index

Profile of Top 20 Most Productive Global Organizations

In global mobile cloud computing research, the productivity of 20 most productive global organizations varied from 22 to 89 publications and together they contributed 18.92% (715) publication share and 37.07% (5913) citation share to its cumulative publications output during 2007-16. The scientometric profile of these 20 organizations is presented in Table 4. Nine of these organizations registered publications output greater than the group average of 35.75. Eight organizations registered impact above the group average of 8.27 citations per publication during 2007-16: Microsoft Research, USA (42.29), University of Melbourne, Australia (23.26), University of Malaya, Malaysia (17.31), Arizona State University, USA (10.89), Sapienza University of Rome, Italy (10.0), Huazhong University of Science and Technology, China (9.29), University of British Columbia, Canada (9.14) and Georgia Institute of Technology, USA (8.55) during 2007-16. Six organizations registered h-index above the group average of 7.05: University of Malaya, Malaysia (17), Arizona State University, USA (11), University of Melbourne, Australia, University of British Columbia, Canada and Tsinghua University, China (9 each) and Huazhong University of Science and Technology, China (8) during 2007-16. Eleven organizations contributed inter-

national collaborative publications share above the group average of 41.82%: University of British Columbia, Canada (78.38%), University of Melbourne, Australia (78.26%), Huazhong University of Science and Technology, China (73.47%), University of Ottawa, Canada (72.41%), University of Malaya, Malaysia (64.81%), King Saud University, Saudi Arabia (61.54%), Aalto University, Finland (56.25%), Sapienza University of Rome, Italy (52.0%), Tsinghua University, China (49.06%), Xidian University, China (47.37%) and Arizona State University, USA (44.33%) during 2007-16. Eight organizations registered the relative citation index above the group average (1.96) of all organizations: Microsoft Research, USA (10.02), University of Melbourne, Australia (5.51), University of Malaya, Malaysia (4.10), Arizona State University, USA (2.58), Sapienza University of Rome, Italy (2.37), Huazhong University of Science and Technology, China (2.20), University of British Columbia, Canada (2.16) and Georgia Institute of Technology, USA (2.02) during 2007-16.

Profile of Top 20 Most Productive Authors

In the field of global mobile cloud computing, the research productivity of top 20 most productive authors varied from 13 to 34 publications. Together they contributed 9.98% (377)

Table 5: Scientometric Profile of Top 20 Most Productive Authors In Mobile Cloud Computing Research during 2007-16.

S.No	Name of the Author	Affiliation of the Author	TP	TC	CPP	HI	ICP	%ICP	RCI
1	A.Gani	University of Malaya, Malaysia	34	699	20.56	15	18	52.94	4.87
2	R. Deters	University of Saskatchewan, Canada	33	96	2.91	5	2	6.06	0.69
3	V C M Leung	University of British Columbia, Canada	28	253	9.04	9	24	85.71	2.14
4	E N Huh	Kyung Hee University, South Korea	26	21	0.81	3	3	11.54	0.19
5	M. Chen	Huazhong University of Science and Technology, China	22	220	10	7	18	81.82	2.37
6	D. Huang	Arizona State University, USA	22	281	12.77	8	12	54.55	3.03
7	R.K. Lomotey	University of Saskatchewan, Canada	22	67	3.05	5	2	9.09	0.72
8	R. Buyya	University of Melbourne, Australia	19	488	25.68	8	15	78.95	6.09
9	Y. Jaraweh	Jordan University of Science and Technology	18	80	4.44	5	12	66.67	1.05
10	E. Ahmed	University of Malaya, Malaysia	15	244	16.27	8	12	80	3.85
11	X. Chen	Xidian University, China	15	73	4.87	5	7	46.67	1.15
12	M. Shiraz	University of Malaya, Malaysia	15	298	19.87	9	2	13.33	4.71
13	S.N. Srirama	University of Tartu, Estonia	15	134	8.93	8	5	33.33	2.12
14	M. Qiu	Pace University, USA	14	62	4.43	3	10	71.43	1.05
15	A.V.Vasilakos	National Technical University, Athens, Greece	14	306	21.86	8	10	71.43	5.18
16	S. Abolfazli	University of Malaya, Malaysia	13	350	26.92	7	10	76.92	6.38
17	F.Flores	University of Tartu, Estonia	13	78	6	6	2	15.38	1.42
18	B. Kantarci	University of Ottawa, Canada	13	48	3.69	3	9	69.23	0.87
19	J. Li	Guangzhou University, China	13	71	5.46	5	8	61.54	1.29
20	X. Liu	Beijing University of Post and Telecommunications, China	13	4	0.31	1	0	0	0.07
		Total of 20 authors	377	3873	10.27	6.4	181	48.01	2.43
		Total of World	3779	15950	4.22				
		Share of top 20 authors in World total output	9.98	24.28					

TP=Total Papers; TC=Total Citations; CPP=Citations Per Paper; HI=h-index; ICP=International Collaborative Papers; RCI=Relative Citation Index

Table 6: Top 20 Most Productive Journals in Mobile Cloud Computing Research during 2007-16.

S.No	Name of the Journal	Number of Papers		
		2007-11	2012-16	2007-16
1	Mobile Networks and Applications	2	25	27
2	Future Generation Computer Systems	0	25	25
3	Journal of Supercomputing	0	24	24
4	Multimedia Tools and Applications	0	18	18
5	Wireless Personal Communication	1	17	18
6	IEEE Network	0	16	16
7	IEEE Systems Journal	0	16	16
8	IEEE Wireless Communication	0	16	16
9	IEEE Transactions on Cloud Computing	0	15	15
10	Journal of Network and Computer Applications	0	15	15
11	IEEE Communication Magazine	0	14	14
12	Cluster Computing	1	12	13
13	Concurrency Computation	0	13	13
14	Security and Communication Networks	0	13	13
15	Simulation Modeling Practice and Theory	0	13	13
16	IEEE Transaction on Parallel and Distributed Systems	1	11	12
17	International Journal Applied Engineering Research	0	12	12
18	IEEE Access	0	11	11
19	IEEE Transaction on Emerging Topics in Computing	0	11	11
20	Journal of Internet Technology	1	10	11
	Total of 20 journals	6	307	313
	Total global journal output	64	979	1043
	Share of top 20 journals in global journal output	9.38	31.36	30.01

Table 7: List of Significant Keywords in Literature on Mobile Cloud Computing during 2007-16.

S.No	Keyword	Frequency	S.No	Keyword	Frequency	S.No	Keyword	Frequency
1	Mobile Computing	2696	17	Network Architecture	162	33	Cloud Service Providers	71
2	Mobile Devices	1497	18	Network Security	161	34	Mobile Ad Hoc Networks	70
3	Mobile Cloud Computing	1382	19	Social Networking (Online)	149	35	Mobile Learning	69
4	Distributed Computer Systems	791	20	Middleware	126	36	Wireless Sensor Networks	60
5	Mobile Telecommunication Systems	649	21	Internet of Things	124			
6	Mobile Applications	464	22	Health Care	119	37	Mobile Cloud Applications	59
7	Mobile Security	445	23	Virtual Reality	113	38	Cloud Computing Platform	56
8	Digital Storage	366	24	Cloud Computing Environment	108	39	Software Engineering	55
9	Internet	351	25	Cloud Computing Technology	96	40	Mobile Internet	53
10	Mobile Clouds	275	26	Artificial Intelligence	90	41	Cloud Storage	51
11	Web Services	257	27	Cloud Infrastructures	88	42	Cloudlet	51
12	Smart Phones	245	28	Embedded Systems	79			
13	Cryptography	237	29	Mobile Agents	79			
14	Cloud Services	196	30	Global Systems of Mobile Communications	75			
15	Big Data	180	31	Cloud Computing Services	73			
16	Clouds	170	32	Cloud Environment	72			

global publication share and 24.28% (3873) citation share during 2007-16. The scientometric profile of these 20 authors is presented in Table 5 Eight authors registered publications output above the group average of 18.85: A. Gani (34 publications), R. Deters (33 publications), V C M Leung (28 publications), E N Huh (26 publications), D. Huang, M. Chen and R.K. Lomotey (22 publications each) and R. Buyya (19 publications) during 2007-16. Eight authors registered impact above the group average of 9.68 citations per publication: S. Abolfazli (26.92), R. Buyya (25.68), A.V.Vasilakos (21.86), A.Gani (20.56), M. Shiraz (19.87), E. Ahmed (16.27), D. Huang (12.77) and M. Chen (10.0) during 2007-16. Nine authors registered h-index above the group average of 6.4 of all authors: A.Gani (15), M. Shiraz and V C M Leung (9 each), R. Buyya, A.V.Vasilakos, E. Ahmed, D. Huang and S.N. Srirama (8 each) and S. Abolfazli (7) during 2007-16. Twelve authors contributed international collaborative publications share above the group average of 44.99% of all authors: V C M Leung (85.71%), M. Chen (81.82%), E. Ahmed (80.0%), R. Buyya (78.95%), S. Abolfazli (76.92%), A.V.Vasilakos and M. Qiu (71.43% each), B. Kantarci (69.23%), Y. Jaraweh (66.67%), J. Li (61.54%), D. Huang (54.55%) and A.Gani (52.94%) during 2007-16. Seven authors registered the relative citation index above the group average (2.29) of all authors: S. Abolfazli (6.38), R. Buyya (6.09), A.V.Vasilakos (5.18), A.Gani (4.87), M. Shiraz (4.71), E. Ahmed (3.85) and D. Huang (3.03) during 2007-16.

Medium of Communication

Of the total world output in mobile cloud computing, 74.66% (28784) appeared as conference papers, 16.38% (5673) in journals, 8.29% (2872) in book series, 0.47% (162) in trade publications and 0.20%(70) in books. The top 20 most productive journals accounted for 11 to 27 papers each in mobile cloud computing and together accounted for 30.01% share (313 papers) of total journal publication output during 2007-16. The publication shares of these top 20 most productive journals increased from 9.38% to 31.36% between 2007-11 and 2012-16. The top most productive journal (with 27 papers) was *Mobile Networks and Applications*, followed by *Future Generation Computer Systems* (25 papers), *Journal of Supercomputing* (24 papers), *Multimedia Tools and Applications* (18 papers), etc. during 2007-16 Table 6.

Significant Keywords

Around 42 significant keywords have been identified from the literature, which point to possible trends in mobile cloud computing research. These keywords are listed in Table 7 in the decreasing order of the frequency of occurrence during 2007-16.

Highly Cited Papers

A total of 15 highly cited papers were identified which received citations from 99 to 848 during 2007-16 (Appendix-1). These

15 papers together received 3834 citations, which averaged to 255.6 citations per paper. Of the 15 highly cited papers, 6 resulted from the participation of single organization (non-collaborative) and 9 involved the participation of two or more organizations (all international collaborative). Among international collaborative papers, the largest participation was from France (7 papers), followed by Australia, China and Malaysia (4 papers each), South Korea (2 papers), New Zealand, Singapore, Hong Kong, Saudi Arabia and Pakistan (1 papers each). The 15 highly cited papers involved the participation of 26 authors and 27 organizations. Among the various organizations involved, University of Malaya, Malaysia accounted for 4 papers, University of Melbourne, Australia (3 papers), Purdue University, USA (2 papers), and 1 paper each from: (i) USA- Carnegie Mellon University, Microsoft Research, AT and T Labs, Walmart Labs, Utah State University, University of Buffalo, State University of New York, Virginia Polytechnic University Institute, Huawei Research Center, Samsung Information Systems America and North Dakota State University; (ii) China – University of Science and Technology, Microsoft Research Asia and Tsinghua University; (iii) Australia-La Trobe University; (iv) South Korea- LG Electronics-Seoul and Kyung Hee University; (v) Singapore- Nanyang Technological University; (vi) New Zealand-Lincoln University; (vii) U.K.- Lancaster University; (viii) Hong Kong-City University of Hong Kong; (ix) Saudi Arabia- King Abdulaziz University and (x) Pakistan – COMSATS Institute of Information Technology. Among the authors R. Buyya and A Gani contributed three papers each, S.Abolfazli, Z Sanaei, K. Kumar and Y H Lu contributed 2 papers each, and 20 other authors accounted for 1 paper each. Of the 15 highly cited papers, 12 were published as articles, 2 as review papers and 1 as conference paper. These 15 highly cited papers were published in 8 journals, of which 4 papers were published in IEEE Communication Surveys & Tutorials, 2 papers in Mobile Networks & Applications, and 1 paper each in IEEE Pervasive Computing, IEEE Transactions on Parallel & Distributed Systems, IEICE Transactions on Communications, Computer, Future Generation Computer Systems, Science of the Total Environment, Wireless Communication & Mobile Computing and Journal of Internet Technology.

CONCLUSION

Using the Scopus database, this study provides a quantitative and qualitative description of the development of the research involving mobile cloud computing over a period of 10 years. From 2007 to 2016 the scientific literature related to mobile cloud computing registered a high growth of 139.6% per annum. However, qualitative performance of mobile computing literature measured in terms of citation impact is not as stunning.

Compared to quantitative performance it averaged to mere 4.22 citations per paper in 10 years period.

China is the top most productive country in the world in mobile cloud computing research. The other Asian countries joining the top 10 most productive countries in 2007-16: India (ranked 3rd), South Korea (4th), Taiwan (6th), and Malaysia (10th). From the western world, the USA ranked 2nd amongst the top 10 most productive countries, followed by Canada (5th), the UK (7th), Germany (8th) and Italy (9th). Five of top 10 most productive countries performed comparatively better in qualitative terms, scoring relative citation index above the world average of 1: Malaysia (2.41), USA (1.87), U.K. (1.79), Canada (1.43) and Italy (1.16) during 2007-16. The 10 most productive countries collectively accounted for the bulk of the global publication share (85.74%) during 2007-16. Their international collaborative publications share varied widely from 9.74% to 67.19%, in mobile cloud computing research during 2007-16. Computer Science accounts for the largest share (85.79%) in mobile computing research, followed by engineering (28.37%), mathematics and social sciences (10.64% and 5.58% respectively) etc. during 2007-16. The top 20 most productive research organizations and the authors collectively contributed 18.92% and 9.98% respectively as their global publication share and 37.07% and 24.28% respectively as their global citation share during 2007-16. Of the total mobile cloud computing research, only 15 publications registered high citations, in the range of 99 to 848 citations per paper, and collectively these 15 highly cited papers received a total of 3834 citations, averaging to 255.60 citations per paper. These 15 highly cited papers involved the participation of 26 authors and 27 organizations.

The conference proceedings medium has emerged as the mode of publishing research in mobile cloud computing accounting for 74.6% global share. The journals as a publication medium ranked 2nd, accounting for 16.4% share of total mobile cloud computing literature. The top 20 most productive journals involving mobile cloud computing accounted for 30% share of total publications output in journals during 2007-16. The most productive journals include *Mobile Networks and Applications*, *Future Generation Computer Systems*, *Journal of Supercomputing*, *Multimedia Tools and Applications* during the 10-year period analysed 2007-16.

Conclusively, the Asian countries (China, India, South Korea, Taiwan, and Malaysia) dominate mobile cloud computing research more in quantitative terms compared to the western countries (the USA, the UK, Canada, Italy) which on the other hand dominate research more in qualitative terms. For enabling Asian countries to perform better in qualitative terms in future, it is desirable that the stakeholders in these nations should strive to give high priority to research in this area and promote international collaborative research, in particular,

with leading mobile cloud computing hubs located in the western counties.

REFERENCES

- Vogels WA. A head in the clouds -The power of infrastructure as a service. In Proceedings of the First workshop on Cloud Computing and in Applications (CCA '08). 2008.
- Armbrust M et al. Above the clouds. A Berkeley review of cloud computing. Electrical Engineering and Computer Sciences, University of California at Berkeley. Technical Report No. UCB/EECS-2009-28. February 10, 2009. <http://www.eecs.berkeley.edu/Pubs/TechRpts/2009/EECS-2009-28.html>
- Fernando N, Loke SW, Rathayu W. Mobile cloud computing: A survey. *Future Generation Computer Systems*. 2013;29(1):84-106.
- Ibukun E and Daramola O. A systematic literature review of mobile cloud computing. *International Journal of Multimedia and Ubiquitous Engineering*. 2015;10(12):135-52.
- Dev D, Baishnab KL. A review and research towards mobile cloud computing (Conference Paper). Proceedings - 2nd IEEE International Conference on Mobile Cloud Computing, Services, and Engineering, MobileCloud 2014. 2014, Article number 6834971, Pages 252-256. 2nd IEEE International Conference on Mobile Cloud Computing, Services, and Engineering, MobileCloud 2014; Oxford; United Kingdom; 7 April 2014 through 10 April 2014; Category number E2504; Code 106057.
- Dinh TH, Lee C, Niyato D, Wang P. A survey of mobile cloud computing: Architecture, application and approaches. *Wireless Communications and Mobile Computing* December. 2013;13(18):1587-611. DOI: 10.1002/wcm.1203.
- Ibukun E, Daramola O. A systematic literature review of mobile cloud computing. *International Journal of Multimedia and Ubiquitous Engineering*. 2015; 10(12):135-52.
- Cai Y, Lu V, Wang L, Xing W. Cloud computing research analysis using bibliometric method. *International Journal of Software Engineering and Knowledge Engineering*. 2015;25(3):551-71. DOI: <http://dx.doi.org/10.1142/S0218194015400203>.
- Gupta BM, Singh N, Gupta R. International cloud computing literature: A scientometric analysis for 2004-13. *Information Studies* April and July. 2015;21(2-3):111-31.
- Gupta BM, Singh N, Gupta R. Indian cloud computing research: A scientometric assessment of publications output during 2004-13. *SRELS Journal of Information Management* October. 2015;52(5):315-26.
- Gupta BM, Dhawan SM, Gupta R. World mobile research: A scientometric assessment of research publications output during 2007-16. *Library Philosophy and Practice* (e-journal). 2017, Paper 1551. <http://digitalcommons.unl.edu/libphilprac/1551>.
- Dhawan SM, Gupta BM, Gupta R. Mobile computing: A scientometric assessment of global publications output. *Annals of Library and Information Studies* September. 2017;64(3):172-80.
- Andersson B. Mobile Computing from a Developer's Perspective: A 10-Year Review, 1999-2008. Perspectives. In. Business Informatics Research. 2010; 64:220-33. <http://dx.doi.org/10.1007/978-3-642-16101-8-18>.
- Ladd DA, Datta A, Sarker S, Yu Y. Trends in mobile computing within the IS Discipline: A ten-year retrospective. *Communications of the Association for Information Systems*. 2010;27(17). Available at: <http://aisel.aisnet.org/cais/vol27/iss1/17>.
- Gupta BM, Kumar Anoop and Gupta R. Global publications output on mobile learning during 2007-16. *International Journal of Information Dissemination and Technology*. 2017;7(3):190-5.
- Gupta R, Gupta BM, Kumar A. Mobile banking: A scientometric assessment of global publications output during 2007-16. *International Journal of Information Dissemination and Technology*. 2017;7(2):128-34.
- Gupta R, Gupta BM, Kumar A. Mobile payment research: A scientometric assessment of global publications output during 2007-16. *International Journal of Information Dissemination and Technology*. 2017;7(2):110-15.

Appendix 1. List of Highly Cited Papers

- Satyanarayanan M, Bahl P, Cáceres R, Davies N. The case for VM-based cloudlets in mobile computing (Article). *IEEE Pervasive Computing*. 2009; 8(4):14-23. Cited 848 times.
- Kumar K, Lu YH. Cloud computing for mobile users: Can offloading computation save energy? (Article). *Computer*. 2010;43(4):51-6. Cited 519 times.
- Fernando N, Loke SW, Rahayu W. Mobile cloud computing: A survey (Review). *Future Generation Computer Systems*. 2013;29(1):84-106. Cited 425 times.
- Robinson BHE-waste: An assessment of global production and environmental impacts (Review). *Science of the Total Environment*. 2009;408(2):183-91. Cited 412 times.
- Dinh HT, Lee C, Niyato D, Wang P. A survey of mobile cloud computing: Architecture, applications, and approaches (Article). *Wireless Communications and Mobile Computing*. 2013;13(18):1587-611. Cited 337 times.
- Kumar K, Liu J, Lu YH, Bhargava B. A survey of computation offloading for mobile systems (Article). *Mobile Networks and Applications*. 2013;18(1):129-40. Cited 161 times.
- Yuan J, Zheng Y, Xie X, Sun G. Driving with knowledge from the physical world (Conference Paper). Proceedings of the ACM SIGKDD International Conference on Knowledge Discovery and Data Mining. 2011:316-24. Cited 157 times.
- Fu Z, Sun X, Liu Q, Zhou L, Shu J. Achieving efficient cloud search services: Multi-keyword ranked search over encrypted cloud data supporting parallel computing (Article). *IEICE Transactions on Communications*. 2015;E98B(1):190-200. Cited 156 times.
- Cao N, Wang C, Li M, Ren K, Lou W. Privacy-preserving multi-keyword ranked search over encrypted cloud data (Article). *IEEE Transactions on Parallel and Distributed Systems*. 2014;25(1):222-33. Cited 152 times.
- Zhang X, Kunjithapatham A, Jeong S, Gibbs S. Towards an elastic application model for augmenting the computing capabilities of mobile devices with cloud computing (Article). *Mobile Networks and Applications*. 2011;16(3):270-84. Cited 129 times.
- Ren Y, Shen J, Wang J, Han J, Lee S. Mutual verifiable provable data auditing in public cloud storage (Article). *Journal of Internet Technology*. 2015;16(2):317-23. Cited 122 times.
- Abolfazli S, Sanaei Z, Ahmed E, Gani A, Buyya R. Cloud-based augmentation for mobile devices: Motivation, taxonomies, and open challenges (Article). *IEEE Communications Surveys and Tutorials*. 2014;16(1):337-68. Cited 111 times.
- Sanaei Z, Abolfazli S, Gani A, Buyya R. Heterogeneity in mobile cloud computing: Taxonomy and open challenges (Article). *IEEE Communications Surveys and Tutorials*. 2014;16(1):369-92. Cited 105 times.
- Shiraz M, Gani A, Khokhar RH, Buyya R. A review on distributed application processing frameworks in smart mobile devices for mobile cloud computing (Article). *IEEE Communications Surveys and Tutorials*. 2013;15(3):1294-313. Cited 101 times.
- Khan AJR, Othman M, Madani SA, Khan SU. A survey of mobile cloud computing application models (Article). *IEEE Communications Surveys and Tutorials*. 2014;16(1):393-413. Cited 99 times.