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A bibliometric overview of the Journal of Network and Computer Applications between 1997 and 2019

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Abstract

A bibliometric analysis of the Journal of Network and Computer Applications (JNCA) for the 1997-2019 period is performed. This analysis uncovers the structural and hidden implications of this journal. JNCA is one of the most prestigious journals in the computer science and engineering research community. Clarivate Analytics Web of Science is used to extract the bibliometric data on which the analysis is performed. The study begins with the publication and citation structure. Analysis of the most influential papers is discussed next. Detailed information on leading authors, institutions and countries is also presented. Analysis of the co-citations, bibliographic coupling, and co-occurrence of keywords was performed with the help of VOSviewer as a visualization tool. Alongside visual analysis, temporal and global analyses are also presented for the co-citation analysis and co-occurrence analysis.

Keywords: Bibliometrics; journal; JNCA; Web of Science; VOSviewer.

1. Introduction

The Journal of Network and Computer Applications (JNCA) was established in the year 1996. It was previously known as "*Journal of Microcomputer Applications*." JNCA extended its scope and editorial board in January 1996. From that date onwards, JNCA has accepted several document types, such as articles, editorials, reviews and proceedings papers, in the related areas of computer networks and computer applications. JNCA publishes documents in the specific fields of network tools, emerging Internet protocol standards, mobile computing, wireless networks, grid computing, cloud computing, Internet of Things (IoT), 5G, and security aspects in computers and networks. Of course, the general subject area of 'networks and computer applications' opens a wide array of research scopes and attracts authors from different domains.

Bibliometric studies are intended for the intrinsic analysis of any research field. This area of study is receiving significant attention from the scientific community. Often also referred to as 'Scientometrics', it involves the statistical analysis of the publications in a specific area or a journal. Therefore, an aerial overview of the scientific area can easily be visualized. Various performance aspects are considered for the analysis, including top publications, citation structure, productive and influential authors, contributing countries and institutions. For a long time, this field was considered as a subfield of library and information sciences; however, in the last 5-10 years, bibliometric analysis has started to exhibit its own identity, attracting attention from diverse areas such as business, economics, psychology and computer science.

Examples of computer science- and engineering-related areas where bibliometrics have been utilized include Aggregation operator research [1], Accounting research [8], Fuzzy decision-making [2], Ordered weighted averaging operators [3], Atanassov intuitionistic fuzzy sets [4], Fuzzy research [5], Linguistic decision-making studies [6], Real-time operating systems [7], Industry 4.0 [19] and Economics in Latin America [9]. Apart from the subject-specific bibliometric study, there have been noteworthy journal-specific studies, which give an overall picture of the journal's statistics. Journals for which bibliometric studies have been performed include: Knowledge Based Systems [10], International Journal of Intelligent Systems [11], IEEE Transactions on Fuzzy Systems [12], European Journal of Operations Research [13], Computers & Industrial Engineering [14], Information Sciences [15-16], Applied Soft Computing [17], Neurocomputing [18], Engineering Application of Artificial Intelligence [20], Knowledge management [21], and Group Decision and Negotiation [22].

The major contribution of this paper is a bibliometric analysis of JNCA over the years 1997-2019. The outcome of the analysis includes the publication and citation structure, most influential papers, leading authors, institutions and countries, co-citation analysis of the journals citing JNCA, bibliographic coupling of the institutions and countries, and co-occurrence of the authors' keywords. This study will help the editors of JNCA, authors publishing in the journal, and readers of the journal to obtain an overall intrinsic structure of the journal since its inception, as well as hidden interpretations. Moreover, it also shows the

productivity of the journal, which helps in assessing the journal regarding future goals and vision.

The paper contains five sections. Section 2 explains the data collection and methodology followed in this paper. The results are provided in Section 3, which includes the citation and publication landscape, influential papers, and lists of leading authors, institutions and countries. Section 4 is all about visualization using the widely used VOSviewer software. Various analyses are performed, such as co-citation analysis, bibliographic coupling, and co-occurrence of author keywords. The paper concludes in Section 5 with a summary of the findings and outcomes.

2. Methods

Data collection and interpretation are the most crucial parts of the bibliometric analysis. The data for this study is collected from the widely used repository Web of Science (WoS) Core Collection, which is made available by Clarivate Analytics. WoS indexes quality publications from top journals and ranked international conferences. Two indexes were selected for the search query: the Science Citation Index (SCI)-Expanded and Social Science Citation index. These two indexes are regarded as the standard indexing data source. There are over 12000 journals currently aligned as SCI bibliographic index. The search query for the data collection was performed in March 2020. The query used was: "SO = Journal of Network and Computer Applications," which retrieved a total of 2349 publications. The outcome of the query provided several fields, including title, author, affiliation, abstract and citations.

Although the variable used in each section is defined alongside the analysis, a few commonly used variables are the total number of publications (TP), total citations received by a publication (TC), and number of publications (say, N) of an entity that has received more than N citations (Hirsch index or H-index) [23].

To go deeper into the results, the work develops a graphical analysis by using VOS viewer [24]. VOS viewer is a piece of computer software that collects the bibliographic data and produces graphical maps that visualize the results according to different techniques, including co-citation analysis [25], bibliographic coupling [26] and co-occurrence of author keywords [16]. Recall that co-citation occurs when two documents receive a citation by the same third document. Bibliographic coupling measures the most productive variables, identifying those that cite the same documents more frequently. Co-occurrence of author keywords measures the most common keywords and those that appear more frequently in the same papers.

3. Results

This section, which contains three subsections, presents the statistical analysis on the extracted data. First, we discuss the publication and citation landscape of JNCA since 1997. After that, the top 50 most influential (most cited) papers are displayed. In the last subsection, we list the leading authors, institutions and countries publishing in JNCA.

3.1. Publication and citation structure of JNCA

Fig. 1 shows the total number of publications over the years 1997-2019. Although the number of publications is uneven throughout the years, JNCA gradually increased its publications until 2019 (TP=2,349). The first year, 1997, had 25 publications, which increased to 213 publications in 2010. The last 10 years (2010-2019) present a total of 1,949 publications, while the earlier years (1997-2007) produced only 256 papers. During the first ten years of the journal (1997-2006), the journal published an average of around eighteen papers per year. The first decline in the number of publications was observed for the year 2007 with a TP of 75. The highest number of publications (TP=270) was recorded in the year 2016.

The total citation structure of JNCA can be seen in Table 1. It has received a significant TC of 38,611 up to April 2020. The growth pattern for the citations is the same as that for the total publications. The citation count of the last 10 years (33,176) is 9 times greater than that of the earlier years (TC=3,669). The highest citation count was received in the year 2014, with a TC of 5,705. There are 13 papers with more than 200 citations (0.55%), 48 papers with more than 100 citations (2.04%), 163 papers with more than 50 citations (6.94%), 485 papers with more than 20 citations (20.65%), and 959 papers with more than 10 citations (40.83%).

From a general point of view, it is remarkable that JNCA is growing significantly over time. This can also be seen by looking to the impact factor of the journal, which has been growing significantly over time, with JNCA becoming a leading journal in the field of Computer Science. In the 2018 edition of the Journal Citation Report (JCR) of the WoS, the journal achieved an impact factor of 5,273, being ranked 6th of 53 journals in the field of Computer Science, Hardware & Architecture, 8th of 106 journals in Computer Science, Interdisciplinary Applications, and 6th of 107 journals in Computer Science, Software Engineering. In all of these fields, the journal is ranked as a quartile 1 (Q1) journal (Top 25%). Fig. 2 presents the evolution of the impact factor of the journal since 1997.
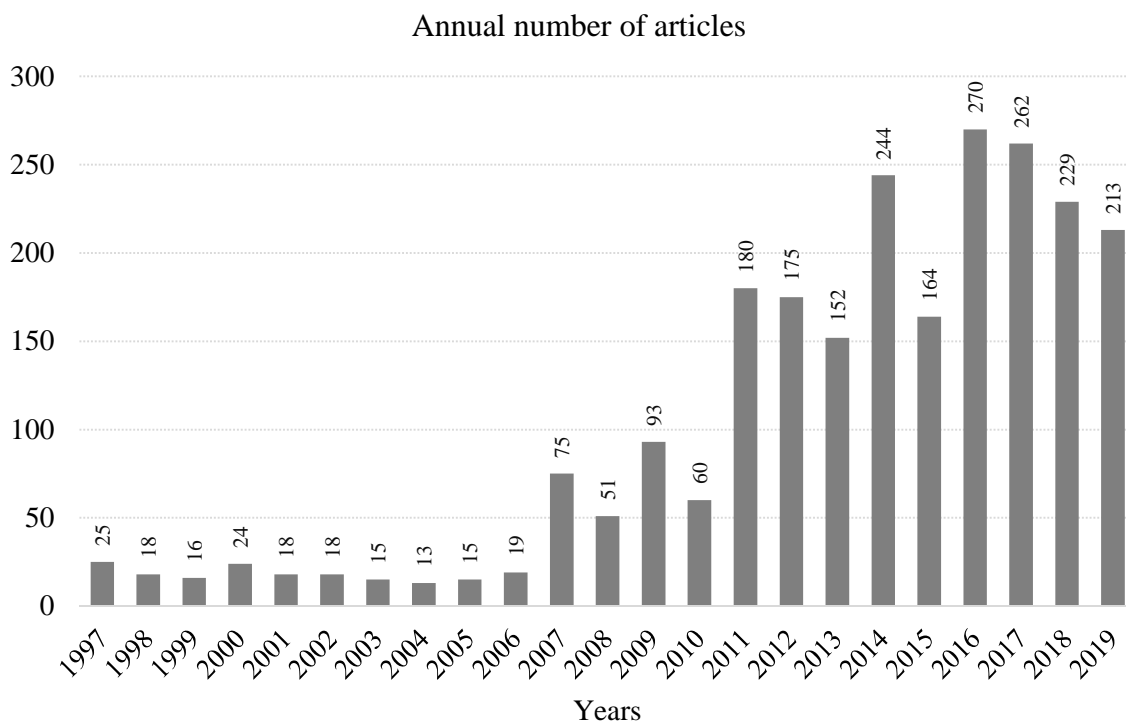
Annual number of articles

Fig. 1: Annual number of papers published in JNCA.

Table 1: Annual citation structure of JNCA.

Year	TP	TC	>=500	>=200	>=100	>=50	>=20	>=10	>=5	>=1
1997	25	86	0	0	0	0	1	3	5	13
1998	18	73	0	0	0	0	1	3	5	13
1999	16	151	0	0	0	1	2	4	7	14
2000	24	571	0	1	2	2	2	5	10	19
2001	18	194	0	0	1	1	2	4	5	13
2002	18	123	0	0	0	1	1	4	6	15
2003	15	117	0	0	0	0	2	2	9	13
2004	13	124	0	0	0	0	0	6	11	13
2005	15	800	0	1	2	3	5	10	12	1
2006	19	130	0	0	0	0	1	3	12	18
2007	75	1,300	0	0	2	8	20	33	47	68
2008	51	629	0	0	0	1	8	24	43	49
2009	93	1,137	0	0	1	4	15	38	64	93
2010	60	1,083	0	0	1	6	14	29	48	60
2011	180	4,890	1	1	8	20	60	93	132	177
2012	175	4,186	0	2	7	21	57	94	133	169
2013	152	3,727	0	2	7	17	44	85	124	151
2014	244	5,705	0	4	9	22	63	130	176	237
2015	164	2,752	0	0	2	12	41	81	130	161
2016	270	5,347	0	2	4	28	78	138	203	261
2017	262	3,454	0	0	2	11	48	111	171	252
2018	229	1,644	0	0	0	4	17	52	100	205
2019	213	388	0	0	0	0	3	7	23	116
Total	2,349	38,611	1	13	48	162	485	959	1476	2,131
%	100.00%		0.04%	0.55%	2.04%	6.90%	20.65%	40.83%	62.84%	90.72%

Abbreviations: TP and TC = Total papers and total citations; >200, >100, >50, >20, >10, >5, >1 = Numbers of papers with more than 200, 100, 50, 20, 10, 5 and 1 citations.
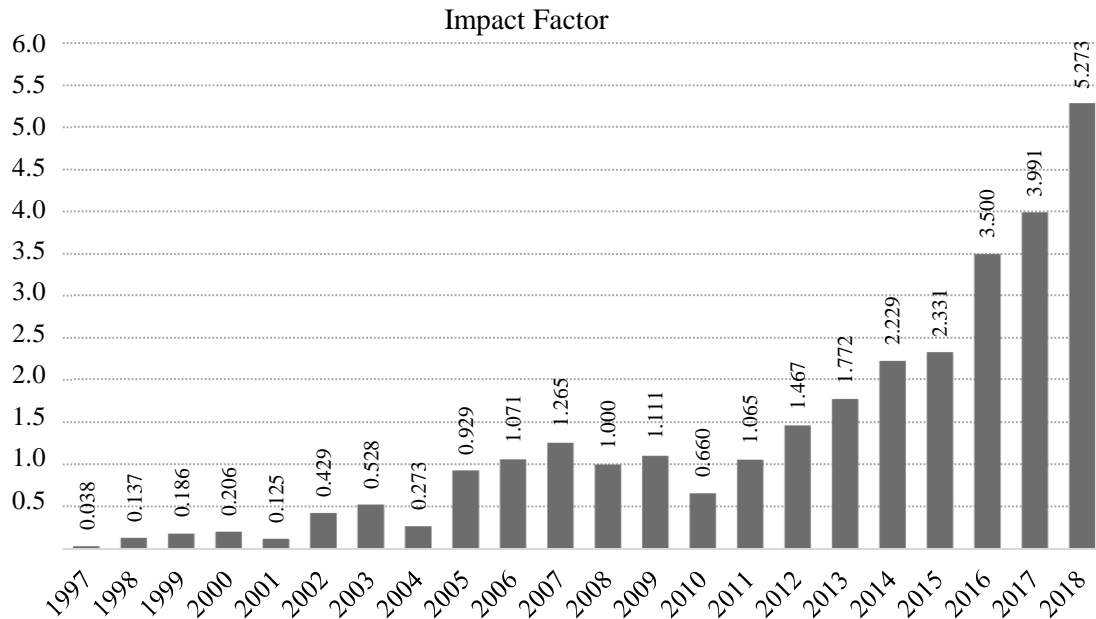
Fig. 2: Impact Factor of JNCA.

3.2. Editorial Board and Workflow

Mohammed Atiquzzaman is serving as the Editor in Chief since 2007. In addition to the EIC, the current editorial board consists of 55 editors from 19 countries, including two Senior Editors (Jiang Xie and Jose Neuman de Souza). Since 2014, regular submissions to JNCA follow a workflow which starts with the Editor-in-Chief who is responsible to assign them to the Senior Editors who oversee the screening phase. In that phase papers can be rejected or sent for review. During the screening process papers are evaluated in their overall structure, looking at aspects like scope, proofreading, main contributions to the research fields, achievements and so on. If a paper passes the screening phase, the full review phase is handled by the Area Editors who are responsible to obtain at least three reviews.

3.3. Influential papers in JNCA

Table 2 lists the 50 most cited papers in JNCA. Apart from the paper title, it also contains the TC, author name, year of publications and citations per year. Here, R stands for Rank, and C/Y is the citations per year. There are 48 papers with 100 citations or more. The 2011 publication entitled "*A survey on security issues in service delivery models of cloud computing*" by Subashini and Kavitha [27] tops the list with a TC of 990. It is followed by "*A comprehensive survey on vehicular Ad Hoc*" (TC=478, Year=2014) and "*A service-oriented middleware for building context-aware services*" (TC=428, Year=2008) authored by Al-Sultan et al. and Gu et al. [33,28], respectively. Among all of the 50 top cited papers, 20 of them are survey papers. The important number of survey papers appearing in the list of top cited papers is explained by researchers' need for an essential overview of a topic. It is also an interesting observation to take into account by researchers looking for a high number of citations.

In this most cited papers list, 84% (TP=42) of the papers were published after 2010. The year 2014 accounts for 9 papers, 2011 and 2012 have 8 papers each, and 2013 has 7 papers. This analysis shows that recent publications in the last 10 years are the most influential in

JNCA. There are only two papers in this list with a single author. The first one is "*An overview of the Internet of Things for people with disabilities*" from Carmen Domingo with 237 citations [30], and the other is "*On-line learning migration: from social learning theory to social presence theory in a CMC environment*" from Tu with 106 citations [31].

The highest rate of citations per year (123.75) is obtained by the highly cited paper [27] in the list of the top 50 papers. It is followed by the 49th ranked paper from Hu, P. et. al [32] (Year=2018, TC=99) entitled "*Survey on fog computing: architecture, key technologies, applications and open.*" There is only one paper with more than 100 citations per year.

Table 3 lists the top 40 most cited documents by JNCA publications. This is different from Table 2, as we list here the documents being published anywhere: JNCA, other journals, books or conference proceedings. Table 3 also contains the year of publication, first author name, journal name, volume of the publication, page number, document type, TC and co-citation. The 2002 paper published in Computer Networks by Akyildiz was cited 43 times in JNCA publications. This author is also listed 5 additional times as a first author in this table. The second position paper received 32 citations in JNCA publications. The paper was published in 2010 at Communications of ACM. The most cited JNCA publication by JNCA papers is ranked No. 7 in this list: a paper authored by S. Subashini and published in 2011.

Table 2: The 50 most cited documents in JNCA.

R	TC	Title	Author/s	Year	C/Y
1	990	A survey on security issues in service delivery models of cloud computing	Subashini, S.; Kavitha, V.	2011	123.75
2	478	A comprehensive survey on vehicular Ad Hoc network	Al-Sultan, S; Al-Doori, MM.; Al-Bayatti, AH.; et al.	2014	95.60
3	428	A service-oriented middleware for building context-aware services	Gu, T; Pung, HK; Zhang, DQ	2008	38.91
4	404	A survey on trust management for Internet of Things	Yan, Z; Zhang, P; Vasilakos, AV.	2014	80.80
5	360	The data grid: Towards an architecture for the distributed management and analysis of large scientific datasets	Chervenak, A; Foster, I; Kesselman, C; et al.	2000	18.95
6	333	A survey on vehicular cloud computing	Whaiduzzaman, Md; Sookhak, M; Gani, A; et al.	2014	66.60
7	292	Intrusion detection system: A comprehensive review	Liao, HJ; Lin, Chun-Hung R; Lin, YC et al.	2013	48.67
8	281	A survey of intrusion detection techniques in Cloud	Modi, C; Patel, D; Borisaniya, B; et al.	2013	46.83
9	251	A survey on coverage and connectivity issues in wireless sensor networks	Zhu, C; Zheng, C; Shu, L; et al.	2012	35.86
10	237	An overview of the Internet of Things for people with disabilities	Carmen Domingo, M	2012	33.86
11	225	Dynamic energy-aware cloudlet-based mobile cloud computing model for green computing	Gai, K; Qiu, M; Zhao, H; et al.	2016	75.00
12	215	Applications of wireless sensor networks for urban areas: A survey	Rashid, B; Rehmani, MH	2016	71.67
13	208	Resource management for Infrastructure as a Service (IaaS) in cloud computing: A survey	Manvi, SS.; Shyam, GK	2014	41.60
14	187	Clustering in sensor networks: A literature survey	Afsar, MM; Tayarani-N, Mohammad-H.	2014	37.40
15	181	A survey of network anomaly detection techniques	Ahmed, M; Mahmood, AN; Hu, J	2016	60.33
16	176	State-of-the-art, challenges, and open issues in the integration of Internet of things and cloud computing	Diaz, Ml; Martin, C; Rubio, B	2016	58.67
17	176	Trust mechanisms in wireless sensor networks: Attack analysis and countermeasures	Yu, Y; Li, K; Zhou, W; et al.	2012	25.14
18	175	A systematic review on clustering and routing techniques based upon LEACH protocol for wireless sensor networks	Tyagi, S; Kumar, N	2013	29.17
19	171	Mobile recommender systems in tourism	Gavalas, D; Konstantopoulos, C; Mastakas, K; et al.	2014	34.20
20	170	An efficient and security dynamic identity based authentication protocol for multi-server architecture using smart cards	Li, X; Xiong, Y; Ma, J; et al.	2012	24.29
21	170	Intrusion detection using an ensemble of intelligent paradigms	Mukkamala, S; Sung, AH; Abraham, A	2005	12.14
22	165	Modeling intrusion detection system using hybrid intelligent systems	Peddabachigari, S; Abraham, A; Grosan, C; et al.	2007	13.75
23	160	Cryptanalysis and improvement of a biometrics-based remote user authentication scheme using smart cards	Li, X; Niu, JW; Ma, J; et al.	2011	20.00
24	156	Primary radio user activity models for cognitive radio networks: A survey	Saleem, Y; Rehmani, MH	2014	31.20
25	154	A survey on routing techniques in underwater wireless sensor networks	Ayaz, M; Baig, I; Abdullah, A; et al.	2011	19.25
26	152	Wireless sensor network key management survey and taxonomy	Zhang, J; Varadharajan, V	2010	16.89
27	150	Opportunistic IoT: Exploring the harmonious interaction between human and the internet of things	Guo, B; Zhang, D; Wang, Z; et al.	2013	25.00
28	149	An intrusion detection and prevention system in cloud computing: A systematic review	Patel, A; Taghavi, M; Bakhtiyari, K; et al.	2013	24.83
29	146	A survey on virtual machine migration and server consolidation frameworks for cloud data centers	Ahmad, RW; Gani, A; Ab Hamid, Siti H; et al.	2015	36.50
30	145	Mutual information-based feature selection for intrusion detection systems	Amiri, F; Yousefi, M; Lucas, C; et al.	2011	18.13
31	143	Vehicular communication ad hoc routing protocols: A survey	Sharef, BT.; Alsaqour, RA.; Ismail, M	2014	28.60
32	143	An enhanced smart card based remote user password authentication scheme	Li, X; Niu, J; Khan, MK; et al.	2013	23.83
33	143	Anomaly detection in wireless sensor networks: A survey	Xie, M; Han, S; Tian, B; et al.	2011	17.88
34	139	A secure dynamic identity based authentication protocol for multi-server architecture	Sood, SK.; Sarje, AK.; Singh, K	2011	17.38
35	137	Internet of Things security: A survey	Alaba, FA; Othman, M; Hashem, I; et al.	2017	68.50
36	137	A temporal-credential-based mutual authentication and key agreement scheme for wireless sensor networks	Xue, K; Ma, C; Hong, P; et al.	2013	22.83
37	134	Survey of multipath routing protocols for mobile ad hoc networks	Tarique, M; Tepe, KE; Adibi, S et al.	2009	13.40
38	131	Secure virtualization for cloud computing	Lombardi, F; Di Pietro, R	2011	16.38
39	130	Bi-modal emotion recognition from expressive face and body gestures	Gunes, H; Piccardi, M	2007	10.83

R	TC	Title	Author/s	Year	C/Y
40	127	Classical and swarm intelligence based routing protocols for wireless sensor networks: A survey and comparison	Zungeru, AJ; Ang, LM; Seng, KP	2012	18.14
41	124	Information centric network: Research challenges and opportunities	Vasilakos, AV.; Li, Z; Simon, G; et al.	2015	31.00
42	121	Practical data compression in wireless sensor networks: A survey	Srisooksai, T; Keamarungsi, K; Lamsrichan, P; et al.	2012	17.29
43	116	A dynamic password-based user authentication scheme for hierarchical wireless sensor networks	Das, AK; Sharma, P; Chatterjee, S; et al.	2012	16.57
44	112	Cloud service selection: State-of-the-art and future research directions	Sun, L; Dong, H; Hussain, FK; et al.	2014	22.40
45	108	A survey of intrusion detection in Internet of Things	Zarpelao, BB; Miani, RS; Kawakani, CT; et al.	2017	54.00
46	106	On-line learning migration: from social learning theory to social presence theory in a CMC environment	Tu, CH	2000	5.58
47	105	Cloud security defence to protect cloud computing against HTTP-DoS and XML-DoS attacks	Chonka, A; Xiang, Y; Zhou, W; et al.	2011	13.13
48	104	Digital watermarking in the fractional Fourier transformation domain	Djurovic, I; Stankovic, S; Pitas, I	2001	5.78
49	99	Survey on fog computing: architecture, key technologies, applications and open issues	Hu, P; Dhelim, S; Ning, H; et al.	2018	99.00
50	98	TRIP, a trust and reputation infrastructure-based proposal for vehicular ad hoc networks	Marmol, F; Martinez Perez, G	2012	14.00

Table 3: Top 40 most cited documents in JNCA publications.

Rank	Year	First Author	Reference	Vol	Page	Type	TC	Co-citations
1	2002	Akyildiz IF	Comput Netw	v38	p393	A	43	34
2	2010	Armbrust M	Commun ACM	v53	p50	A	32	26
3	2002	Heinzelman Wb	IEEE T Wirel Commun	v1	p660	A	31	24
4	2010	Atzori L	Comput Netw	v54	p2787	A	29	16
5	2008	Yick J	Comput Netw	v52	p2292	A	29	21
6	2009	Buyya R	Future Gener Comp Sy	v25	p599	A	25	21
7	2011	Subashini S	J Netw Comput Appl	v34	p1	A	24	15
8	2000	Bianchi G	IEEE J Sel Area Comm	v18	p535	A	22	8
9	2005	Akyildiz IF	Comput Netw	v47	p445	A	21	7
10	2002	Camp T	Wirel Commun Mob Com	v2	p483	A	21	7
11	2014	Manvi Ss	J Netw Comput Appl	v41	p424	A	21	14
12	2008	Mckeown N	ACM Sigcomm Comp Com	v38	p69	A	20	16
13	2002	Akyildiz IF	IEEE Commun Mag	v40	p102	A	19	14
14	1993	Floyd S	IEEE ACM T Network	v1	p397	A	19	4
15	2009	Satyanarayanan M	IEEE Pervas Comput	v8	p14	A	19	18
16	1999	Perkins Ce	Wmcsa '99			P	17	11
17	2004	Younis O	IEEE T Mobile Comput	v3	p366	A	17	15
18	2000	Ahlswede R	IEEE T Inform Theory	v46	p1204	A	16	6
19	2008	Younis M	Ad Hoc Netw	v6	p621	A	16	9
20	2007	Akyildiz IF	Comput Netw	v51	p921	A	15	10
21	1970	Bloom Bh	Commun ACM	v13	p422	A	15	5
22	2011	Calheiros Rn	Software Pract Exper	v41	p23	A	15	12
23	2011	Chun Bg	Eurosys 11		p301	P	15	15
24	2015	Kreutz D	P IEEE	v103	p14	A	15	15
25	2014	Nunes Baa	IEEE Commun Surv Tut	v16	p1617	A	15	14
26	2012	Ahlgren B	IEEE Commun Mag	v50	p26	A	14	10
27	2005	Akkaya K.	Ad Hoc Networks	v3	p325	A	14	12
28	2004	Boyd S	Convex Optimization			B	14	8
29	2001	Cormen T. H.	Intro Algorithms			B	14	7
30	2002	Ye W	IEEE Infocom Ser		p1567	P	14	13
31	2006	Akyildiz IF	Comput Netw	v50	p2127	A	13	9
32	2009	Chandola V	ACM Comput Surv	v41		A	13	4
33	2016	Chang V	Future Gener Comp Sy	v57	p24	A	13	6
34	2010	Cuervo E.	P 8 Int C Mob Syst A		p49	P	13	13
35	2008	Dean J	Commun ACM	v51	p107	A	13	4
36	2013	Fernando N	Future Gener Comp Sy	v29	p84	A	13	13
37	2000	Karp B.	P 6 Ann Int C Mob Co		p243	P	13	8
38	1995	Kennedy J	IEEE Int Conf Neural Netw Proc	vols 1-6	p1942	A	13	8
39	1978	Rivest Rl	Commun ACM	v21	p120	A	13	1
40	2005	Akyildiz IF	Ad Hoc Networks	v3	p257	A	12	8

Abbreviations: TC = Total citations; A = Article; B = Book; P = Proceedings.

3.4. Leading authors, institutions and countries

Table 4 lists the top 50 authors ranked according to the total number of citations among those that have six or more papers published in JNCA. This table also shows the authors' affiliation, country, TC, TP, H-index, C/P, and number of papers with more than 250, 100 and 50 citations. The list begins with A. Gani from University of Malaya, Malaysia with a TC of 1,136 for 22 papers. He is also the author with the highest number of publications and highest H-index of 16. This author is followed by R. Buyya from University of Melbourne, Australia (TC=923, TP=18), A. Vasilakos from Kuwait University, Kuwait (TC=735, TP=8), and K, Choo, from University of Texas at San Antonio, USA (TC=650, TP=22).

All authors in this list have at least 90 citations. In terms of the total number of JNCA publications, the first one is S, Yu from Deakin University followed by two authors with 22

publications each. These authors are A. Gani from University of Malaya, Malaysia, K. Choo from University of Texas at San Antonio. With respect to the countries, 13 authors are from People's Republic of China, 7 are from Australia, 6 are from USA and 5 are from Malaysia.

In terms of H-index, and besides A. Gani, 4 authors, K. Choo from University of Texas at San Antonio, M. K. Khan S from King Saud University, R. Buyya from University of Melbourne, and K. J. Rodrigues, and from ITMO University, have an H-index greater than 10.

There is a change in hierarchy in terms of citations per year. A. Vasilakos takes the lead with a C/P of 91.88, followed by L. Xiong (C/P=87.14) and M. Rehmani (C/P=61.00, U= Waterford Institute of Technology). Interestingly, seven authors have more than 250 citations, i.e., A. Vasilakos and P. Zhang. There are four authors in the top 10 with more than 100 citations, A. Gani from University Malaya, Malaysia, R. Buyya from University of Melbourne, Australia, Z. Yang from Xidian University, People's Republic of China and L. Shu from Osaka University, Tokyo.

The most productive (number of publications) and influential universities (number of citations) in JNCA are shown in Table 5. It also contains the H-index, C/P, Academic Ranking of World Universities (ARWU), QS (QS University Ranking) and numbers of papers with more than 250, 100 and 50 citations.

The most productive university concerning JNCA is Islamic Azad University, Iran with 49 publications. Second and third place are taken by University of Malaya, Malaysia (TP=42) and King Saud University, Saudi Arabia (TP=42), respectively. All of the universities in this list of the top 50 have at least 12 publications. In terms of most influential university, University of Malaya tops the list with 1,774 citations. It is followed by Islamic Azad University and University of Melbourne with total citations of 1,316 and 1,016, respectively. There are 6 universities with more than 800 citations. The remaining three universities are King Saud University, Saudi Arabia, Dalian University of Technology, People's Republic of China, and Xidian University, People's Republic of China. In addition, 48 universities have at least 150 citations.

The University of Malaya has the highest H-index of 24. The second position is held by Islamic Azad University. Then, there are 2 universities with H-indexes of 15: University of Melbourne and King Saud University.

Table 4: Top 50 leading authors in JNCA.

R	Full Name	Afilliation	Country	TC	TP	H	C/P	>250	>100	>50
1	Gani, Abdullah	U Malaya	Malaysia	1,136	22	16	51.64	1	2	7
2	Buyya, Rajkumar	U of Melbourne	Australia	923	18	12	51.28	1	1	7
3	Vasilakos, Athanasios V.	Kuwait U	Kuwait	735	8	6	91.88	1	2	3
4	Choo, Kim-Kwang Raymond	UTSA	USA	650	22	14	29.55	0	0	4
5	Li, Xiong	Beijing Posts Telecom	PRC	610	7	6	87.14	0	3	4
6	Khurram Khan, Muhammad	King Saud U	Saudi Arabia	577	21	12	27.48	0	1	4
7	Rehmani, Mubashir Husain	Waterford Inst Tech	Ireland	549	9	8	61.00	0	2	3
8	Niu, Jianwei	Beihang U	PRC	466	14	9	33.29	0	2	2
9	Yan, Zheng	Xidian U	PRC	463	8	5	57.88	1	1	1
10	Xia, Feng	Dalian U of Technology	PRC	452	9	8	50.22	0	1	4
11	Rodrigues,Joel JPC.	ITMO U	Russia	422	15	10	28.13	0	0	3
12	Shu, Lei	Osaka U	Japan	408	7	6	58.29	1	1	1
13	Kumar, Neeraj	Thapar U	India	390	12	9	32.50	0	1	2
14	Han, Guangjie	Hohai U	PRC	386	10	7	38.60	1	1	1
15	Manvi, Sunilkurnar S	Reva Inst of Tech & Management	India	383	8	8	47.88	0	1	1
16	Ahmed, Ejaz	U Malaya	Malaysia	380	7	7	54.29	0	0	5
17	Hu, Jiankun	U of New South Wales Canberra	Australia	379	13	7	29.15	0	1	3
18	Shiraz, Muhammad	Federal Urdu U of Arts	Pakistan	357	8	7	44.63	0	1	2
19	Rajaraja, Muttukrishnan	U of London	UK	355	7	4	50.71	1	1	1
20	Othman, Mohamed	Putra Malaysia U	Malaysia	320	15	8	21.33	0	1	2
21	Navimipour, Nima Jafari	Islamic Azad U	Iran	313	7	6	44.71	0	0	3
22	Anuar, Nor Badrul	U of Malaya	Malaysia	279	9	9	31,00	0	0	1
23	Li, Peng	Chinese Acad Sci	PRC	273	8	6	34.13	0	1	1
24	Zhang, Yaoyu	Xidian U	PRC	270	16	9	16.88	0	0	1
25	Fortino, Giancarlo	U of Calabria	Italy	253	9	7	28.11	0	0	2
26	Xiang, Yang	Deakin U	Australia	218	10	7	21.80	0	1	1
27	Yu, Shui	Deakin U	Australia	200	25	9	8.00	0	0	0
28	Jha, Rakesh Kumar	Shri Mata Vaishno Devi U	India	197	7	5	28.14	0	0	2
29	Rahmani, Amir Masoud	Islamic Azad U	Iran	187	9	6	20.78	0	0	1
30	Masdari, Mohammad	Islamic Azad U	Iran	170	7	5	24.29	0	0	2
31	Qiu, Tie	Dalian U Technol	PRC	168	7	4	24.00	0	1	1
32	Zeadally, Sherali	U Kentucky, Coll	USA	147	8	5	18.38	0	0	1
33	Younis, Mohamed	U Maryland Baltimore Cty	USA	145	7	5	20.71	0	0	2
34	Guo, L Jay	U of Michigan	USA	144	13	8	11.08	0	0	0
35	Khan, Suleman	U Malaya	Malaysia	143	7	4	20.43	0	0	1
36	Qadir, Junaid	NUST, Islamabad	Pakistan	135	7	6	19.29	0	0	0

R	Full Name	Afilliation	Country	TC	TP	H	C/P	>250	>100	>50
37	Misra, Sudip	Indian Inst of Technology	India	133	7	5	19.00	0	0	1
38	Li, Jin	Guangzhou U	PRC	124	10	5	12.40	0	0	1
39	Tari, Zahir	RMIT U	Australia	122	7	3	17.43	0	0	1
40	Meng, Weizhi	City U Hong Kong	PRC	115	7	6	16.43	0	0	0
41	Khalil, Ibrahim	RMIT U	Australia	110	11	5	10.00	0	0	0
42	Wang, Yu	Deakin U	Australia	107	7	5	15.29	0	0	0
43	Lorenz, Pascal	Inst U de Tech de Colmar	France	106	7	3	15.14	0	0	1
44	Chen, Jiann-Liang	National Taiwan U of Science & Technology	PRC	104	9	7	11.56	0	0	0
45	Li Chunlin	Wuhan U of Technology	PRC	100	11	6	9.09	0	0	0
46	De Turck, Filip	Ghent U	Belgium	99	16	5	6.19	0	0	0
47	Atiquzzaman, Mohammed	U Oklahoma	USA	97	9	6	10.78	0	0	0
48	Li, Ying	U New Hampshire	USA	93	7	4	13.29	0	0	0
49	You, Ilsun	Soonchunhyang U	South Korea	92	8	4	11.50	0	0	0
50	Wang, Yong	U Elect Sci & Technol	PRC	91	7	5	13.00	0	0	0

Abbreviations are available in the previous tables except for: H = H-index; C/P = Citations per paper; U = University; PRC = People's Republic of China.

Interestingly, University of Melbourne has the highest C/P of 44.17 with 23 papers and total citations of 1016. This shows the high-quality publications from this university with great impact in the research community. University Malaya is in second place with a C/P of 42.24. Then, there are three universities with TPs of only 14 and 19 but 3rd, and 4th place in C/P. These universities are: Polytech University of Catalonia, Spain (C/P=38.14), and University of South Australia (C/P=34.95).

Some other productive and influential institutions in JNCA are listed in Table 6. There are 6 institutions: 3 from People's Republic of China, 2 from France and 1 each from Italy and Australia. The top ranked institution is the Chinese Academy of Sciences with 1,016 citations in 65 papers. It is followed by CNR, Italy, which received 303 citations in just 11 papers, thus attaining the highest C/P of 27.54.

The analysis of the top 50 countries contributing to JNCA is presented in Table 7. Since this is a country-wise analysis, we have shown two different indexes in the table apart from the indexes available in Table 5, which are TP/Pop (Total papers per million inhabitants) and TC/Pop (Total citations per million inhabitants). These two quantifiers are quite unique performance metrics showing the overall productivity of the contributing countries. The table is sorted on the basis of total citations.

People's Republic of China is the most influential and productive country with a total number of citations of 10,938 in 733 papers. Consequently, its H-index of 45 is high, and also, three papers have more than 250 citations. There are 12 papers with more than 100 citations and 36 papers with more than 50 citations. Now, being the most populated country in the world, its TP/Pop and TC/Pop are only 0.51 and 7.63. Other influential countries after People's Republic of China are USA (TC=5,163, TP=338), Australia (TC=4,825, TP=212), India (TC=4,365, TP=183), and Malaysia (TC=3,662, TP=118). The ranking of the top 3 influential countries is the same with respect to productivity.

The standing of these 50 countries changes significantly in terms of C/P. Kuwait has the highest C/P of 109.25 with just 4 papers and 437 total citations. Romania, Malaysia, Thailand and Finland come next with C/Ps of 39.00, 31.03, 30.67, and 28.05, respectively. People's Republic of China, which was at the top spot as the most influential and productive country, is at the 31st spot with a C/P of 14.92. Noticeably, there are a total of 10 countries besides People's Republic of China with a paper having more than 250 citations. These countries include: USA, India, UK, Singapore, and Finland.

Table 5: The most productive and influential universities in JNCA.

R	University	Country	TC	TP	H	C/P	>250	>100	>50	ARWU	QS
1	U Malaya	Malaysia	1,774	42	24	42.24	1	3	12	301-400	114
2	Islamic Azad U	Iran	1,316	49	21	26.86	0	1	10	-	-
3	U of Melbourne	Australia	1,016	23	15	44.17	1	1	7	38	41
4	King Saud U	Saudi Arabia	933	42	15	22.21	0	1	6	101-150	221
5	Dalian U of Technology	PRC	861	25	12	34.44	0	3	6	201-300	551-600
6	Xidian U	PRC	831	28	13	29.68	1	1	3	-	-
7	Deakin U	Australia	739	37	13	19.97	0	2	3	201-300	293
8	COMSATS U Islamabad CUI	Pakistan	736	28	13	26.29	0	2	3	-	-
9	Beijing U of Posts Telecomm	PRC	709	34	13	20.85	0	2	3	-	-
10	U of South Australia	Australia	664	19	14	34.95	0	0	5	-	279
11	Beihang U	PRC	618	29	11	21.31	0	2	3	201-300	551-600
12	Royal Melbourne Inst of Tech	Australia	540	26	13	20.77	0	1	4	-	-
13	Polytechnic U of Catalonia	Spain	534	14	9	38.14	0	1	3	-	275
14	National U of Singapore	Singapore	525	13	6	40.38	1	1	1	85	15
15	U of New South Wales Sydney	Australia	439	23	8	19.09	0	2	2	101-150	45
16	Thapar Inst of Eng Technology	India	418	15	9	27.87	0	1	2	-	-
17	U of Technology Sydney	Australia	416	13	7	32.00	0	2	3	301-400	176
18	U of Texas at San Antonio	USA	412	18	11	22.89	0	0	2	-	-
19	Hohai U	PRC	408	12	8	34.00	1	1	1	-	-
20	Guangzhou U	PRC	404	19	10	21.26	0	0	3	-	-
21	Northeastern U China	PRC	403	26	12	15.50	0	0	2	401-500	-
22	U of Calabria	Italy	380	13	9	29.23	0	0	2	-	-
23	U Teknologi Malaysia	Malaysia	357	18	11	19.83	0	0	2	-	253
24	U Putra Malaysia	Malaysia	352	21	9	16.76	0	1	2	-	229
25	National U Sci Tech Pakistan	Pakistan	336	20	11	16.80	0	0	1	-	431-440
26	U Da Beira Interior	Portugal	331	14	9	23.64	0	0	2	-	-
27	Huazhong U of Science Tech	PRC	298	26	10	11.46	0	0	0	151-200	471-480
28	Nanjing U of Inf Sci Tech	PRC	297	12	8	24.75	0	0	2	401-500	-
29	U of Elect Sci Tech of China	PRC	279	28	9	9.96	0	0	0	201-300	-
30	U Carlos III De Madrid	Spain	252	15	8	16.80	0	0	1	-	281
31	Tsinghua U	PRC	242	29	9	8.34	0	0	0	45	25
32	Nanyang Technological U	Singapore	241	38	9	6.34	0	0	0	96	11
33	Wuhan U of Technology	PRC	226	16	8	14.13	0	0	1	301-400	-
34	Xi An Jiaotong U	PRC	203	19	8	10.68	0	0	0	151-200	344
35	Amirkabir U of Technology	Iran	198	15	8	13.20	0	0	0	401-500	501-550

R	University	Country	TC	TP	H	C/P	>250	>100	>50	ARWU	QS
36	U Politecnica de Valencia	Spain	194	17	8	11.41	0	0	0	401-500	-
37	City U of Hong Kong	PRC	192	16	8	12.00	0	0	0	201-300	49
38	U of Ottawa	Canada	188	12	8	15.67	0	0	2	151-200	289
39	Qatar U	Qatar	176	13	5	13.54	0	0	2	-	349
40	U of Naples Federico II	Italy	175	15	8	11.67	0	0	0	201-300	481-490
41	National Taiwan U of Sci Tech	ROC	173	24	8	7.21	0	0	0	-	264
42	Monash U	Australia	172	13	6	13.23	0	0	0	91	60
43	National Cheng Kung U	PRC	171	12	9	14.25	0	0	1	301-400	222
44	Nanjing U	PRC	169	16	9	10.56	0	0	0	151-200	114
45	National Chiao Tung U	PRC	164	24	7	6.83	0	0	0	-	207
46	Central South U China	PRC	160	12	7	13.33	0	0	1	201-300	801-1000
47	U of Sydney	Australia	155	16	7	9.69	0	0	0	68	50
48	U of Patras	Greece	151	15	8	10.07	0	0	0	-	701-750
49	American U of Beirut	Lebanon	142	12	7	11.83	0	0	0	-	235
50	Wuhan U	PRC	134	14	8	9.57	0	0	0	201-300	282

Abbreviations are available in previous tables except for: ARWU = Academic Ranking of World Universities and QS = University Ranking.

Table 6: Other productive and influential institutions in JNCA.

R	University	Country	TC	TP	H	C/P	>250	>100	>50
1	Chinese Academy of Sciences	PRC	1,026	65	16	15.78	0	1	5
4	CNR	Italy	303	11	6	27.54	0	1	2
2	CNRS	France	284	26	8	10.92	0	0	2
3	Inst of Information Eng, CAS	PRC	238	11	5	21.63	0	0	2
7	Australian Defense Force Acad	Australia	208	10	6	20.80	0	1	1
5	INRIA	France	201	10	7	20.10	0	0	0
6	Inst of Computing Tech, CAS	PRC	77	10	6	7.70	0	0	0

PRC = People's Republic of China.

With respect to the population-based analysis, Singapore (TC/Pop=194.00, TP/Pop=11.28) and Australia (TC/Pop=189.22, TP/Pop=8.31) are in first and second place. They are followed by Malaysia (TC/Pop=113.14, TP/Pop=3.65), Kuwait (TC/Pop=102.33, TP/Pop=0.94), and Finland (TC/Pop=96.20, TP/Pop=3.43).

The temporal evolution of the top 40 country publications from 1997-2019 is shown in Table 8. In the starting year of 1997, only nine countries published any paper in JNCA. USA published 11 papers, followed by Singapore with 7 papers. In the first 10 years (1997-2006), USA, UK, and Singapore were the top three contributors with 46, 22 and 18 publications. There were a total of 12 countries with no publications in this period. These countries were: Malaysia, Iran, Pakistan, Portugal, Algeria, Bangladesh, Sweden, Qatar, Ireland, Jordan, Tunisia, and Russia. The trend changed in the following 10 years (2010-2019), where Malaysia and Iran went from last place in the first 10 years with no publications to 114 and 97 publications. Additionally, People's Republic of China became the top contributor in JNCA with 652 publications. USA, Australia and India are next with 254, 179, and 175 publications.

Considering at least one publication in the first 10 years and comparing the percentage growth in the last 10 years, India tops the contribution with 98.92%. The next two countries are USA and Italy with 98.64% and 98.86%, respectively.

Table 9 lists the top 40 universities, countries and journals that have published documents citing JNCA. In universities, Chinese Academy of Sciences has highly cited JNCA with 497 papers, which is highest among all universities. There is another university, Islamic Azad University, which also has cited JNCA with almost 500 papers (TP=493). These two are followed by Beijing University of Posts and Telecommunications (TP=340), King Saud University (TP=305), and COMSATS U Islamabad CUI (TP=255). In this top 40 list, 39 universities have at least 100 papers.

Table 7: The most productive and influential countries in JNCA.

R	Country	TC	TP	H	TC/TP	>250	>100	>50	Population	TC/Pop	TP/Pop
1	PRC	10,938	733	45	14.92	3	12	36	1,470,637,532	7.44	0.50
2	USA	5,163	338	35	15.28	1	5	27	331,002,651	15.60	1.02
3	Australia	4,825	212	35	22.76	1	9	25	25,499,884	189.22	8.31
4	India	4,365	183	30	23.85	2	6	19	1,380,004,385	3.16	0.13
5	Malaysia	3,662	118	34	31.03	1	8	23	32,365,999	113.14	3.65
6	Spain	2,504	154	24	16.26	0	3	11	46,754,778	53.56	3.29
7	UK	2,414	134	22	18.01	2	3	7	67,886,011	35.56	1.97
8	Iran	2,067	102	27	20.26	0	2	13	83,992,949	24.61	1.21
9	France	1,574	97	23	16.23	0	2	7	65,273,511	24.11	1.49
10	Pakistan	1,485	78	20	19.04	0	2	6	220,892,340	6.72	0.35
11	Italy	1,385	85	21	16.29	0	1	6	60,461,826	22.91	1.41
12	Saudi Arabia	1,325	74	20	17.91	0	1	6	34,813,871	38.06	2.13
13	Canada	1,197	106	17	11.29	0	1	6	37,742,154	31.72	2.81
14	South Korea	1,178	89	16	13.24	0	1	6	51,269,185	22.98	1.74
15	Singapore	1,135	66	15	17.20	1	1	3	5,850,342	194.01	11.28
16	Greece	953	51	15	18.69	0	2	4	10,423,054	91.43	4.89
17	Brazil	900	68	14	13.24	0	2	2	212,559,417	4.23	0.32
18	Japan	737	41	12	17.98	1	2	2	126,476,461	5.83	0.32
19	Portugal	675	42	16	16.07	0	0	3	10,196,709	66.20	4.12
20	Finland	533	19	8	28.05	1	1	1	5,540,720	96.20	3.43
21	Turkey	520	41	14	12.68	0	0	2	84,339,067	6.17	0.49
22	Algeria	516	33	13	15.64	0	0	2	43,851,044	11.77	0.75
23	New Zealand	444	25	12	17.76	0	0	2	4,822,233	92.07	5.18
24	Kuwait	437	4	3	109.25	1	1	1	4,270,571	102.33	0.94
25	Sweden	401	15	9	26.73	0	1	2	10,099,265	39.71	1.49
26	Germany	397	46	10	8.63	0	0	2	83,783,942	4.74	0.55
27	Bangladesh	310	20	7	15.50	0	1	1	164,689,383	1.88	0.12
28	Lebanon	257	19	10	13.53	0	0	1	6,825,445	37.65	2.78
29	U Arab Emirates	243	19	8	12.79	0	0	1	9,890,402	24.57	1.92
30	Romania	234	6	4	39.00	0	1	1	19,237,691	12.16	0.31
31	Egypt	221	20	8	11.05	0	0	1	102,334,404	2.16	0.20
32	Jordan	219	13	8	16.85	0	0	1	10,203,134	21.46	1.27
33	Russia	209	12	7	17.42	0	0	1	145,934,462	1.43	0.08
34	Ireland	207	13	7	15.92	0	0	1	4,937,786	41.92	2.63
35	South Africa	193	9	5	21.44	0	0	2	59,308,690	3.25	0.15
36	Thailand	184	6	4	30.67	0	1	1	69,799,978	2.64	0.09
37	Qatar	177	15	5	11.80	0	0	2	2,881,053	61.44	5.21
38	Austria	174	13	5	13.38	0	0	1	9,006,398	19.32	1.44
39	Netherlands	161	11	7	14.64	0	0	0	17,134,872	9.40	0.64
40	Tunisia	155	12	7	12.92	0	0	0	11,818,619	13.11	1.02
41	Belgium	149	22	6	6.77	0	0	0	11,589,623	12.86	1.90
42	Colombia	147	8	7	18.38	0	0	0	50,882,891	2.89	0.16
43	Poland	91	5	4	18.20	0	0	0	37,846,611	2.40	0.13
44	Morocco	81	6	4	13.50	0	0	1	36,910,560	2.19	0.16
45	Oman	77	4	3	19.25	0	0	0	5,106,626	15.08	0.78
46	Denmark	77	10	5	7.70	0	0	0	5,792,202	13.29	1.73
47	Iraq	75	6	4	12.50	0	0	1	40,222,493	1.86	0.15
48	Switzerland	74	6	4	12.33	0	0	0	8,654,622	8.55	0.69
49	Vietnam	69	6	3	11.50	0	0	1	97,338,579	0.71	0.06
50	Mexico	68	9	5	7.56	0	0	0	128,932,753	0.53	0.07

Abbreviations are available in the previous tables except for TP/Pop and TC/Pop = Total papers and citations per million inhabitants. Note that the population is given in thousands.

Table 8: Temporal evolution of the country publications.

R	Country	97	98	99	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	Total
1	PRC	1	0	1	0	3	2	2	4	0	2	19	15	32	24	54	47	60	75	54	82	82	94	80	748
2	USA	11	3	4	10	4	4	2	2	4	2	17	7	14	8	20	13	9	28	20	38	44	33	41	384
3	Australia	0	1	2	1	0	0	0	1	1	4	9	0	14	3	15	15	12	27	11	25	24	22	25	222
4	India	0	1	0	0	0	1	1	0	0	0	0	4	1	2	6	12	6	17	7	26	33	31	35	186
5	Spain	0	1	1	0	0	0	0	0	0	1	2	5	9	6	22	14	16	17	16	13	14	11	6	157
6	UK	2	4	2	4	0	2	2	1	1	4	5	3	5	4	10	11	6	6	8	14	12	15	13	156
7	Malaysia	0	0	0	0	0	0	0	0	0	0	2	1	1	0	3	7	10	23	25	22	11	6	7	118
8	Canada	1	2	0	1	0	0	2	1	2	0	8	3	8	2	8	10	6	10	6	9	7	6	14	115
9	Iran	0	0	0	0	0	0	0	0	0	0	2	1	2	1	8	11	8	15	8	9	21	5	11	102
10	France	0	0	0	1	1	1	0	0	0	0	1	2	1	0	7	8	8	17	7	10	11	13	9	100
11	South Korea	0	0	0	0	1	2	0	0	0	1	6	0	2	3	11	6	3	11	4	11	16	7	5	93
12	Italy	0	0	1	0	0	0	0	0	1	1	1	1	2	1	5	8	4	4	11	9	12	19	5	88
13	Pakistan	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	2	2	7	9	14	18	12	11	78
14	Saudi Arabia	0	1	0	0	0	0	0	2	0	0	0	1	1	1	0	5	5	4	5	17	11	14	7	77
15	Brazil	0	0	0	0	0	0	0	0	0	1	0	0	0	4	4	7	5	4	2	17	11	7	6	69
16	Singapore	7	3	0	1	2	1	2	0	2	0	0	0	2	2	6	5	2	10	3	9	4	4	1	84
17	Greece	0	1	0	0	2	0	2	0	2	0	3	5	4	2	3	6	3	4	3	2	4	3	2	58
18	Germany	1	0	1	4	0	1	1	0	0	0	1	0	0	1	2	6	3	3	3	2	8	5	4	54
19	Portugal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	3	5	5	4	10	5	2	3	42
20	Japan	1	0	0	0	1	3	0	0	1	1	1	1	4	1	2	4	2	3	2	5	1	4	4	48
21	Turkey	0	0	0	0	0	0	0	0	1	0	2	1	4	0	5	2	2	6	3	4	3	1	7	42
22	Algeria	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	4	1	5	2	4	4	5	6	33
23	New Zealand	0	0	0	0	2	0	0	0	0	0	1	0	0	0	1	3	2	1	1	7	3	2	2	27
24	Belgium	0	0	0	0	1	0	0	0	0	0	1	1	1	1	2	2	2	2	1	2	4	1	1	23
25	Egypt	0	0	0	0	0	0	1	1	0	0	0	0	1	0	0	2	0	2	0	4	2	3	4	22
26	Bangladesh	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	0	0	4	2	7	4	20
27	Lebanon	0	0	0	0	1	0	0	1	0	0	1	1	2	1	2	2	0	4	1	1	2	0	0	21
28	U Arab Emirates	0	0	0	0	1	0	0	0	0	0	0	0	1	2	4	1	3	2	0	2	0	1	2	20
29	Finland	0	0	1	1	1	0	0	0	0	0	0	0	0	0	2	0	2	1	2	2	1	4	2	22
30	Sweden	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	4	1	3	3	1	15
31	Qatar	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2	6	3	2	15
32	Austria	2	0	2	0	2	1	0	1	0	1	1	1	0	0	0	0	0	0	0	2	0	0	0	22
33	Ireland	0	0	0	0	0	0	0	0	0	0	2	1	0	0	2	2	1	0	1	0	3	1	0	13
34	Jordan	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	1	1	3	0	2	2	1	13
35	Tunisia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2	2	2	2	2	0	12
36	Russia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	3	1	4	0	12
37	Netherlands	0	0	0	1	1	0	0	0	0	0	0	0	0	1	2	1	1	2	0	1	0	0	1	13
38	Denmark	0	0	0	0	2	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	2	15
39	Mexico	2	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	2	1	2	0	11
40	South Africa	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	0	0	0	3	1	2	0	10

Abbreviations: Each year indicates the number of publications in that year. PRC = People's Republic of China.

In countries, People's Republic of China had published 6,899 papers citing JNCA, which is more than double the papers published by the 2nd-place-holder India with 2,616 papers. USA is just behind India with 2,314 papers. Other countries in the top 10 frequently citing JNCA are: Iran (1080), South Korea (1072), UK (1036), Spain (993), Australia (982), Malaysia (850), and Pakistan (769).

Among journals citing JNCA, JNCA itself has the second highest number of papers: 1,140 papers. The first one is IEEE Access with 1,170 paper. Other journals that have frequently cited JNCA are Sensors (TP=640), Wireless Personal Communications (TP=517), Future Generation Computer Systems (TP=245), Computer Networks (TP=478), and International Journal of Distributed Sensor Networks (TP=368).

Table 9: Citing articles of JNCA: Universities, countries and journals.

R	University	TP	Country	TP	Journal	TP
1	Chinese Academy of Sciences	497	PRC	6,899	IEEE Access	1,170
2	Islamic Azad U	493	India	2,616	J of Network and Computer App	1,140
3	Beijing U of Posts Telecomm	340	USA	2,314	Sensors	640
4	King Saud U	305	Iran	1,080	Wireless Personal Communication	517
5	COMSATS U Islamabad CUI	255	South Korea	1,072	Future Generation Computer Systems	478
8	Uersiti Teknologi Malaysia	222	UK	1,036	Wireless Networks	294
6	Uersiti Malaya	253	Spain	993	Int J of Distributed Sensor Networks	368
7	Xidian U	223	Australia	982	Computer Networks	299
9	Northeastern U China	206	Malaysia	850	Int J of Communication Systems	281
10	Thapar Inst of Eng Technology	195	Pakistan	769	Computer Communications	252
11	Vellore Inst of Technology	186	Saudi Arabia	711	Networks	242
12	Dalian U of Technology	183	Italy	656	J of Supercomputing	236
13	CNRS	177	Canada	648	IEEE Internet of Things J	226
14	Central South U	172	France	613	Cluster Computing	203
15	U of Electronic Sci Technology	170	Brazil	448	Ad Hoc Networks	202
16	Shanghai Jiao Tong U	159	Turkey	395	IEEE Comm Surveys and Tutorials	202
17	Beihang U	150	Germany	341	Multimedia Tools And Applications	194
18	Nanjing U of Inf Science Techn	148	Japan	305	Wireless Comm Mobile Computing	173
19	Huazhong U of Science Techn	142	Portugal	286	Computers Electrical Engineering	171
20	Tsinghua U	138	Greece	276	Information Sciences	169
21	Anna U	134	Singapore	252	Concurrency and Comp Practice Exp	168
22	Wuhan U	131	Algeria	234	KSII Trans On Internet and Inf Syst	154
23	U of New South Wales Sydney	130	Egypt	192	Int J of Adv Computer Scie and App	150
24	Beijing Jiaotong U	125	Sweden	190	Eurasip J Wireless Commun Network	148
25	Uersitat Politecnica De Valencia	122	U Arab Emirates	161	Expert Systems With Applications	141
26	Harbin Inst of Technology	121	Finland	158	Computers Security	119
27	Guangzhou U	118	Jordan	154	IEEE Sensors J	118
28	Nanyang Technological U	118	Tunisia	153	IEEE Trans On Vehicular Technology	118
29	Indian IIT Kharagpur	117	Poland	135	Soft Computing	115
30	Beijing Inst of Technology	115	Iraq	134	Peer to Peer Networking and App	114
31	Deakin U	115	Russia	134	Telecommunication Systems	112
32	Anna U Chennai	112	Belgium	121	Applied Sciences Basel	109
33	Amirkabir U of Technology	111	New Zealand	114	Transa on Emerging Telecom Techn	108
34	Nanjing U of Posts Telecomm	109	Netherlands	113	J of Internet Technology	102
35	U of Texas At San Antonio	108	Ireland	112	IEEE Trans on Industrial Informatics	99
36	Indian Inst of Technology	107	Morocco	107	J of Ambient Intel and Hum Comp	97
37	King Abdulaziz U	105	Mexico	104	Plos One	97
38	South China U of Technology	101	Norway	95	J of Medical Systems	95
39	U of Science Tech Beijing	99	Qatar	87	ACM Computing Surveys	90
40	Wuhan U	96	Vietnam	86	IEEE Systems J	86

Abbreviations available in the previous tables.

4. Mapping JNCA with VOSviewer software

First, we present the co-citation analysis of journals in JNCA. Co-citation analysis is a method of visualizing the citation structure and representing the research connections between entities such as journals, countries, publications, etc. If two entities are co-cited then there will be a link between them, and this link will be thick if there are many co-citations.

We will use VOSviewer to perform this analysis. The results are extracted with a minimum citation threshold of 20 and 100 links.

The VOSviewer visualization also presents nodes grouped into clusters [24]. A cluster will have similar interconnected nodes, which means that nodes having greater co-citation will have the same cluster color. The strength between two nodes is measured by the width of the links between them.

Fig. 3 shows the co-citation analysis of journals [35-37] that have cited JNCA. Three colors (red, blue, and green) are quickly visible with a few sets of interconnected lines between them. JNCA is the largest node with the links connecting all of the other journal nodes. The link between the two nodes represents the co-citation relation between them, which means that they have citation of the other journal. If one journal has cited the other journal more often, then the nodes are closer or may overlap. The three main clusters in Fig. 3 have the following nodes:

1. Cluster 1 (Red): JNCA, Lecture Notes in Computer Science, Future Generation Computer Systems, IEEE Transactions on Parallel and Distributed Systems, Procedia Computer Science, etc.
2. Cluster 2 (Green): Computer Networks, IEEE/ACM Transactions on Networking, IEEE Communications Magazine, ACM Sigcomm Computer Communication Review, etc.
3. Cluster 3 (Blue): Computer Communications, IEEE Wireless Communications, IEEE Transactions on Mobile Computing, etc.
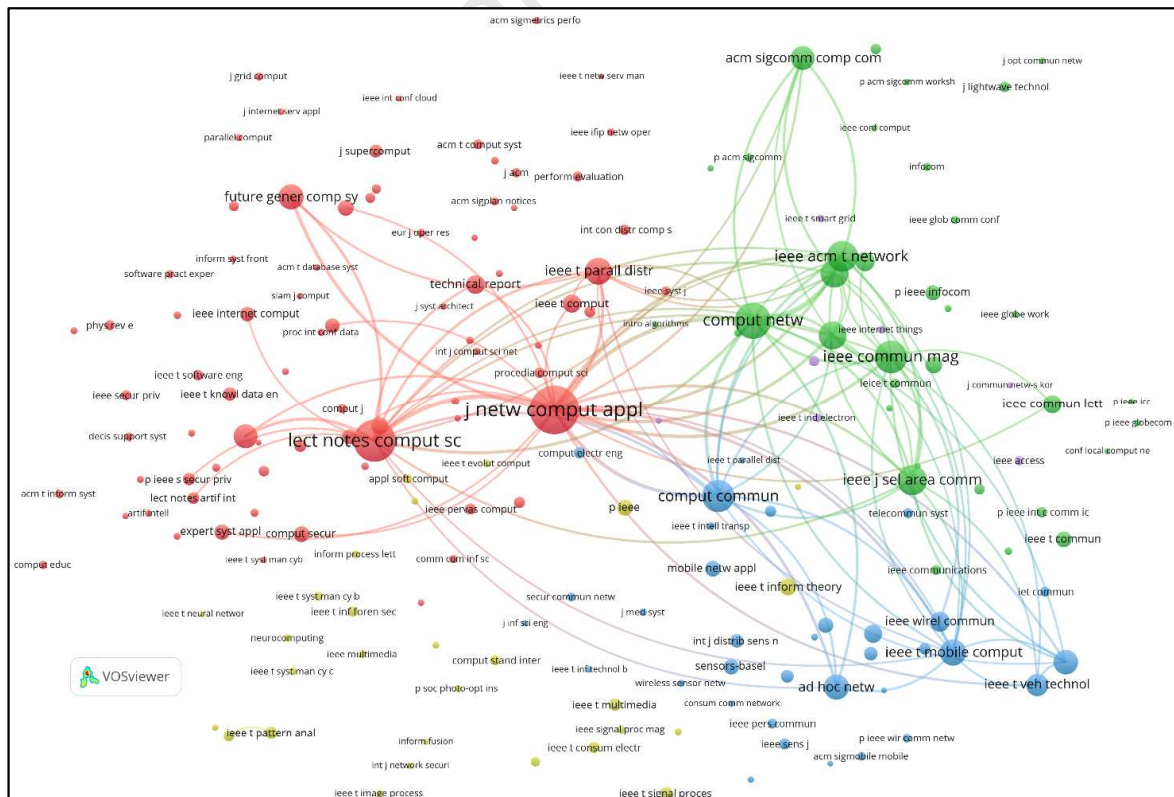
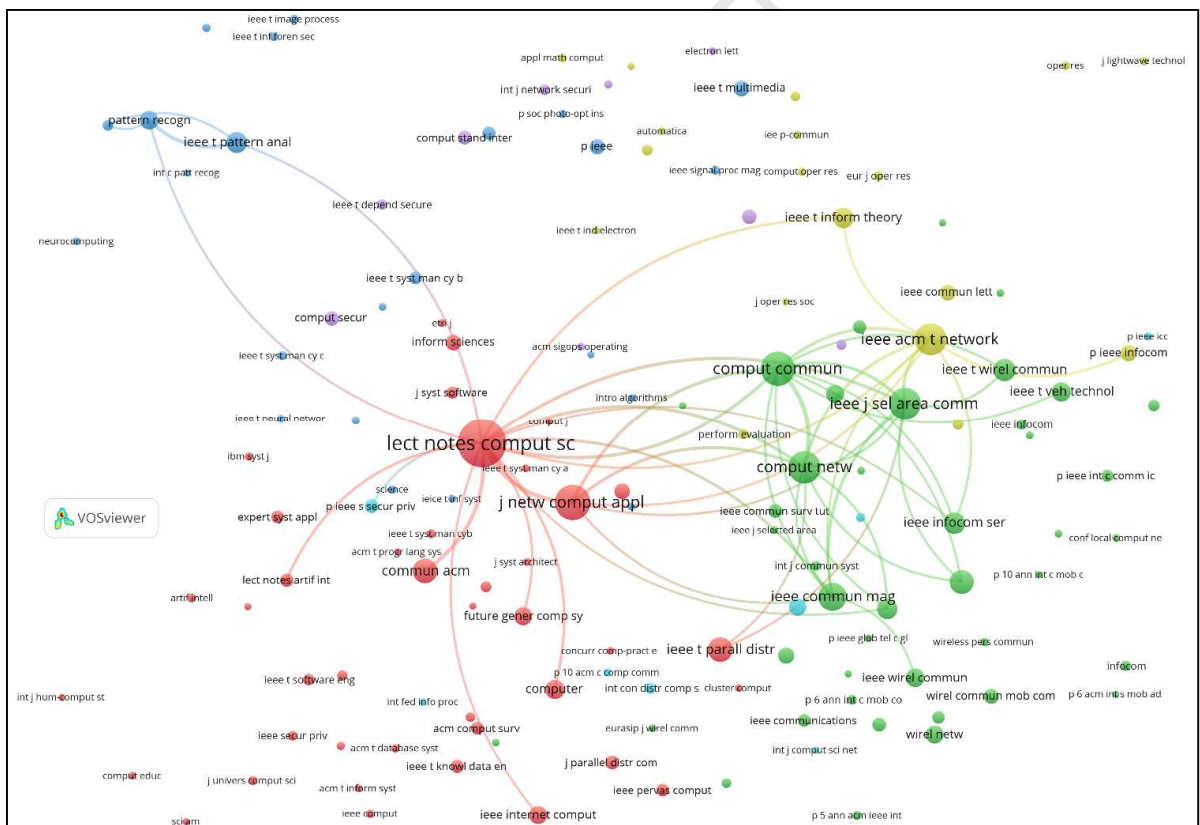Fig. 3: Co-citation of journals citing JNCA: minimum citation threshold of 20 and 100 links.

Extending the co-citation analysis of Fig. 3, we have performed temporal co-citation analysis of journals in Figs. 4-6. Fig. 4 visualizes the co-citation analysis from 1997-2007 (minimum citation threshold=10 and links=100). In the first period (1997-2007), Communications of the ACM is the most prominent node. It is in the red cluster, and it has more links with ACM Transaction on Information Systems and Artificial Intelligence. Other prominent nodes are Lecture Notes in Computer Science (green cluster), IEEE Journal on Selected Areas in Communications (light blue cluster), IEEE/ACM Transactions on Networking (light blue cluster), and IEEE Multimedia (purple cluster). This time era has many colored and scattered clusters, which means that many journals cited JNCA and that the density of co-citations is less important.

The next time span (Fig. 5) is from 2008-2012, with the same minimum citation threshold and links as in Fig. 4. Lecture Notes in Computer Science is the biggest node, representing high co-citation. The journal cluster is red and includes journals such as: JNCA, Communications of the ACM, Future Generation Computer Systems, Information Sciences, and Computer. Other prominent clusters include the journals Computer Communications, IEEE Transaction on Wireless Communications, IEEE Journal on Selected Areas in Communications and Computer Networks.

Fig. 6 is the visualization of the co-citations from 2013-2019 with a minimum citation threshold of 20 and 100 links. Four clusters are prominent in the figure: red, yellow, green and blue. JNCA is the largest node in the red cluster and has co-citations with other clusters. The red cluster includes Future Generation Computing Systems, IEEE Transactions on Parallel and Distributed Systems, Communications of the ACM, and IEEE Transactions on Pattern Analysis and Machine Intelligence. Likewise, Computer networks, IEEE Infocom, IEEE/ACM Transactions on Networking, ACM Sigcomm Computer Communication Review form a yellow cluster due to their co-citations. There are some new journals visible in these years and contained in the green cluster: IEEE Communications Surveys & Tutorials, and IEEE Transactions on Wireless Communications. The blue cluster includes Computer Communications, IEEE Transactions on Mobile Computations, and Ad hoc Networks.
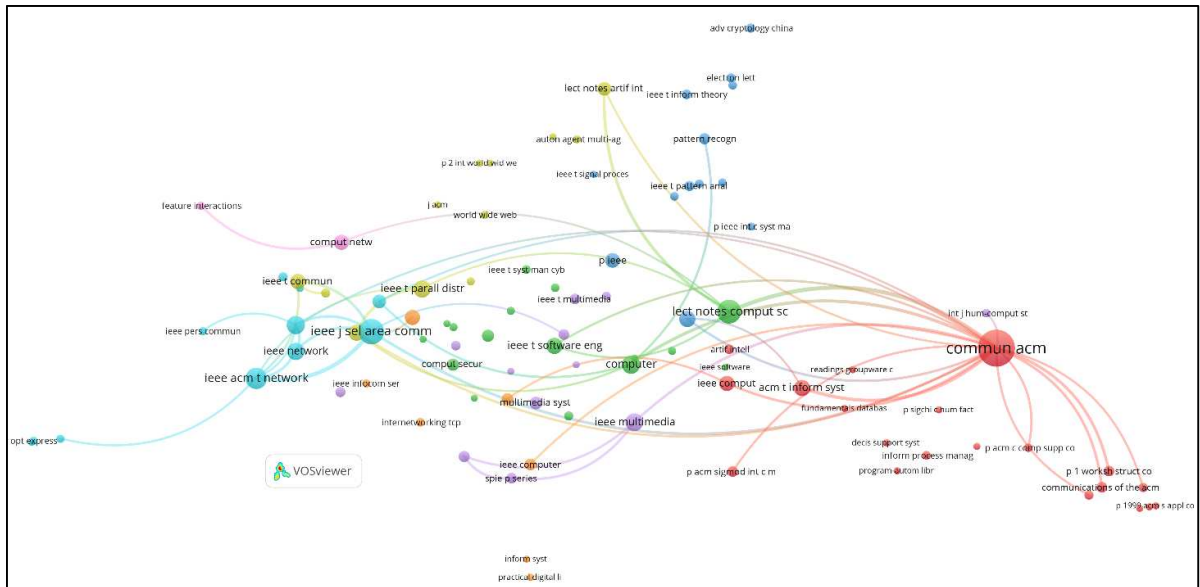
Fig. 4: Co-citation of journals citing JNCA: 1997-2007 (minimum citation threshold of 10 and 100 links).

Fig. 5: Co-citation of journals citing JNCA: 2008-2012 (minimum citation threshold of 10 and 100 links).
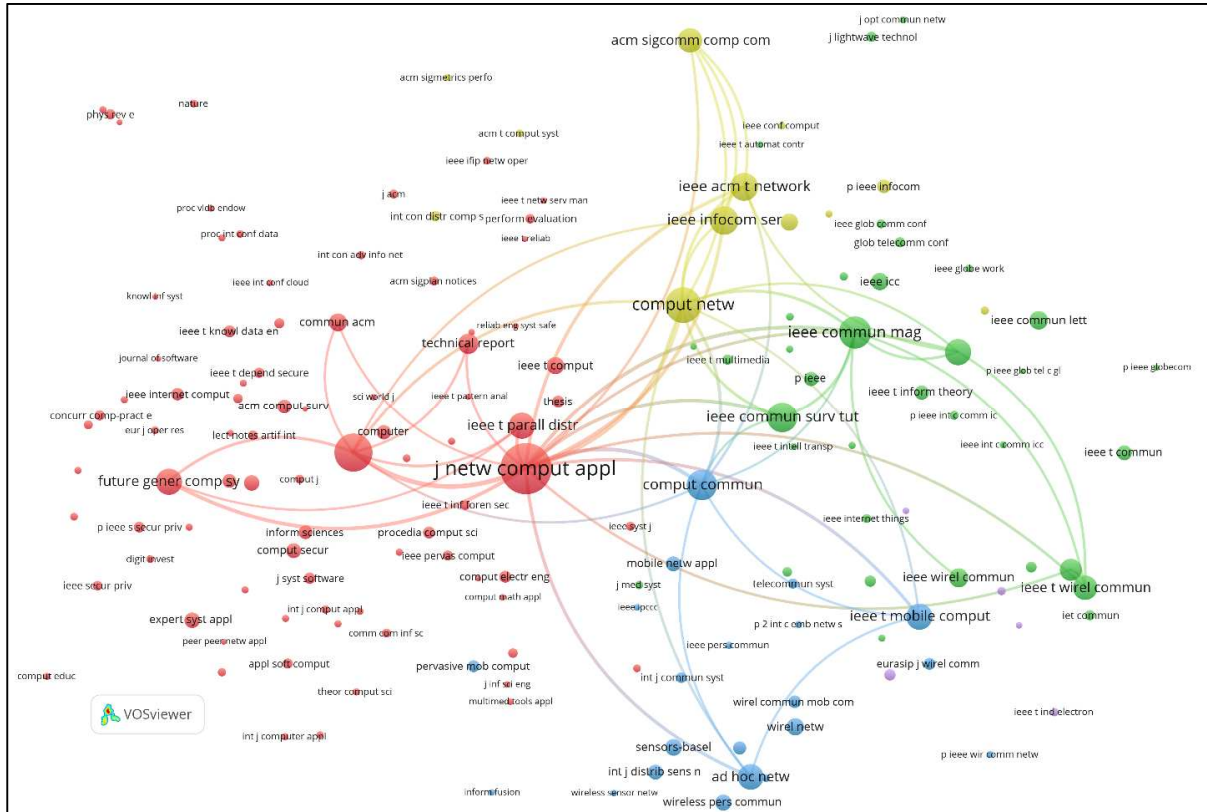
Fig. 6: Co-citation of journals citing JNCA: 2013-2019 (minimum citation threshold of 20 and 100 links).

All of the visualization results in the VOSviewer figures can be verified from the values in Table 10. It shows temporal and global rank-wise citations of journals that cited JNCA. Another column called Citation link strength (CLS) is also included; it represents the co-citation received from the journal. These values numerically quantify the results visualized in Figs. 3-6.

Table 10: Co-citation of journals in JNCA: Global and temporal analysis.

	Global			2013-2019			2008-2012			1997-2007		
R	Journal	Cit	CLS	Journal	Cit	CLS	Journal	Cit	CLS	Journal	Cit	CLS
1	J Netw Comput Appl	1898	1612.24	J Netw Comput Appl	1644	1394.82	Lect Notes Comput Sc	425	320.04	Commun ACM	127	96.31
2	Lect Notes Comput Sc	1379	1145.78	Lect Notes Comput Sc	901	780.60	J Netw Comput Appl	230	192.42	IEEE J Sel Area Comm	59	49.46
3	Comput Netw	1015	949.56	Comput Netw	804	752.49	Comput Commun	217	196.08	Lect Notes Comput Sc	53	44.54
4	IEEE Commun Mag	817	744.01	IEEE Commun Mag	642	582.87	Comput Netw	190	178.48	IEEE ACM T Network	42	38.40
5	Comput Commun	805	751.96	IEEE Commun Surv Tut	571	536.71	IEEE ACM T Network	186	164.12	Computer	31	28.82
6	IEEE ACM T Network	730	662.48	Comput Commun	567	535.10	IEEE J Sel Area Comm	184	171.04	IEEE Commun Mag	31	27.97
7	IEEE J Sel Area Comm	677	634.04	IEEE Infocom Ser	519	478.50	IEEE Commun Mag	144	132.76	IEEE Multimedia	29	24.07
8	IEEE Infocom Ser	611	563.57	IEEE ACM T Network	502	461.76	Commun ACM	112	99.23	IEEE Network	28	22.79
9	IEEE Commun Surv Tut	608	573.61	Future Gener Comp Sy	435	378.34	IEEE T Parall Distr	111	100.72	IEEE T Parall Distr	27	22.47
10	IEEE T Parall Distr	565	521.75	IEEE J Sel Area Comm	434	412.83	IEEE T Mobile Comput	108	101.84	ACM T Inform Syst	25	23.97
11	IEEE T Mobile Comput	543	508.28	IEEE T Wirel Commun	432	402.87	IEEE T Wirel Commun	92	81.89	IEEE T Comput	24	20.18
12	Future Gener Comp Sy	496	431.39	IEEE T Parall Distr	427	399.62	IEEE Infocom Ser	86	79.53	IEEE T Software Eng	24	21.98
13	Ad Hoc Netw	488	457.95	Ad Hoc Netw	410	383.42	IEEE T Pattern Anal	81	65.47	J Netw Comput Appl	24	22.61
14	IEEE T Wirel Commun	463	424.99	ACM Sigcomm Comp Com	377	338.63	IEEE T Inform Theory	78	65.59	IEEE Comput	22	20.00
15	Commun ACM	440	378.84	IEEE T Wirel Commun	369	340.96	Ad Hoc Netw	76	72.19	IEEE T Commun	22	14.31
16	ACM Sigcomm Comp Com	438	395.82	IEEE T Veh Technol	305	287.6	Computer	70	68.69	Comput Commun	21	19.93
17	IEEE T Veh Technol	381	357.22	IEEE Wirel Commun	234	223.68	IEEE T Veh Technol	68	63.56	Comput Netw	21	19.19
18	IEEE Wirel Commun	301	286.81	IEEE Commun Lett	219	211.41	IEEE Wirel Commun	66	61.84	P IEEE	20	18.96
19	IEEE Network	286	276.69	Commun ACM	201	195.70	Pattern Recogn	64	51.15	Comput Networks Isdn	19	17.23
20	IEEE Commun Lett	270	259.62	IEEE Network	196	193.20	IEEE Internet Comput	62	50.35	Lect Notes Artif Int	18	15.73
21	Wirel Netw	263	252.8	IEEE Icc	194	190.88	IEEE Network	62	60.62	ACM T Comput Syst	17	15.71
22	IEEE T Comput	262	247.11	Wirel Netw	193	187.50	Wirel Netw	62	57.98	Multimedia Syst	15	13.96
23	Computer	230	224.15	IEEE T Comput	192	182.05	Future Gener Comp Sy	59	50.75	Comput Secur	14	7.35
24	IEEE Icc	230	226.53	Sensors-Basel	171	147.79	ACM Sigcomm Comp Com	58	54.44	IEEE T Knowl Data En	14	13.85
25	IEEE T Inform Theory	221	195.63	Wireless Pers Commun	166	159.59	Mobile Netw Appl	50	48.81	IEEE Computer	13	12.86
26	Comput Secur	199	175.43	Expert Syst Appl	156	134.41	P IEEE Infocom	50	47.36	IEEE Internet Comput	13	11.62
27	IEEE T Commun	198	180.7	J Parallel Distr Com	150	142.88	IEEE Commun Lett	47	44.17	P Soc Photo-Opt Ins	12	9.63
28	Mobile Netw Appl	192	186.98	Comput Secur	146	132.15	IEEE T Comput	46	43.63	Pattern Recogn	12	7.80
29	P IEEE	192	185.4	IEEE T Commun	142	133.49	IEEE T Multimedia	45	35.18	IEEE T Circ Syst Vid	11	10.15
30	J Parallel Distr Com	189	179.7	Int J Distrib Sens N	141	134.00	Inform Sciences	44	36.94	IEEE T Multimedia	11	9.81
31	Expert Syst Appl	187	164.32	Mobile Netw Appl	138	135.15	P IEEE	43	40.67	P 1 Worksh Struct Co	11	9.89
32	Wireless Pers Commun	182	175.6	ACM Comput Surv	134	127.96	Wirel Commun Mob Com	41	40.37	P ACM Sigmod Int C M	11	10.28
33	Sensors-Basel	179	155.85	IEEE T Inform Theory	134	123.41	Comput Secur	39	35.23	Spie P Series	11	8.11
34	P IEEE Infocom	177	168.88	Computer	129	126.83	IEEE T Consum Electr	39	32.41	IEEE T Pattern Anal	10	8.80
35	IEEE Internet Comput	173	156.78	P IEEE	129	125.73	Comput Stand Inter	37	32.64	P IEEE Infocom	10	9.47
36	ACM Comput Surv	170	164.96	J Supercomput	123	117.80	P IEEE S Secur Priv	37	34.58	Artif Intell	9	7.00
37	Inform Sciences	164	154.01	Inform Sciences	117	113.63	IEEE Commun Surv Tut	36	35.63	IEEE T Inform Theory	9	8.71
38	Int J Distrib Sens N	145	138.12	P IEEE Infocom	117	112.29	IEEE Icc	36	35.53	P ACM Sigcomm	9	8.75
39	IEEE T Knowl Data En	141	133.18	ACM T Sensor Network	112	105.64	IEEE Pers Commun	36	35.73	ACM T Database Syst	8	7.54
40	Wirel Commun Mob Com	140	138.87	IEEE Sens J	99	94.38	J Parallel Distr Com	35	32.97	IEEE T Veh Technol	8	5.57

Abbreviations: R = Rank; Cit = Citations; CLS = Citation link strength.
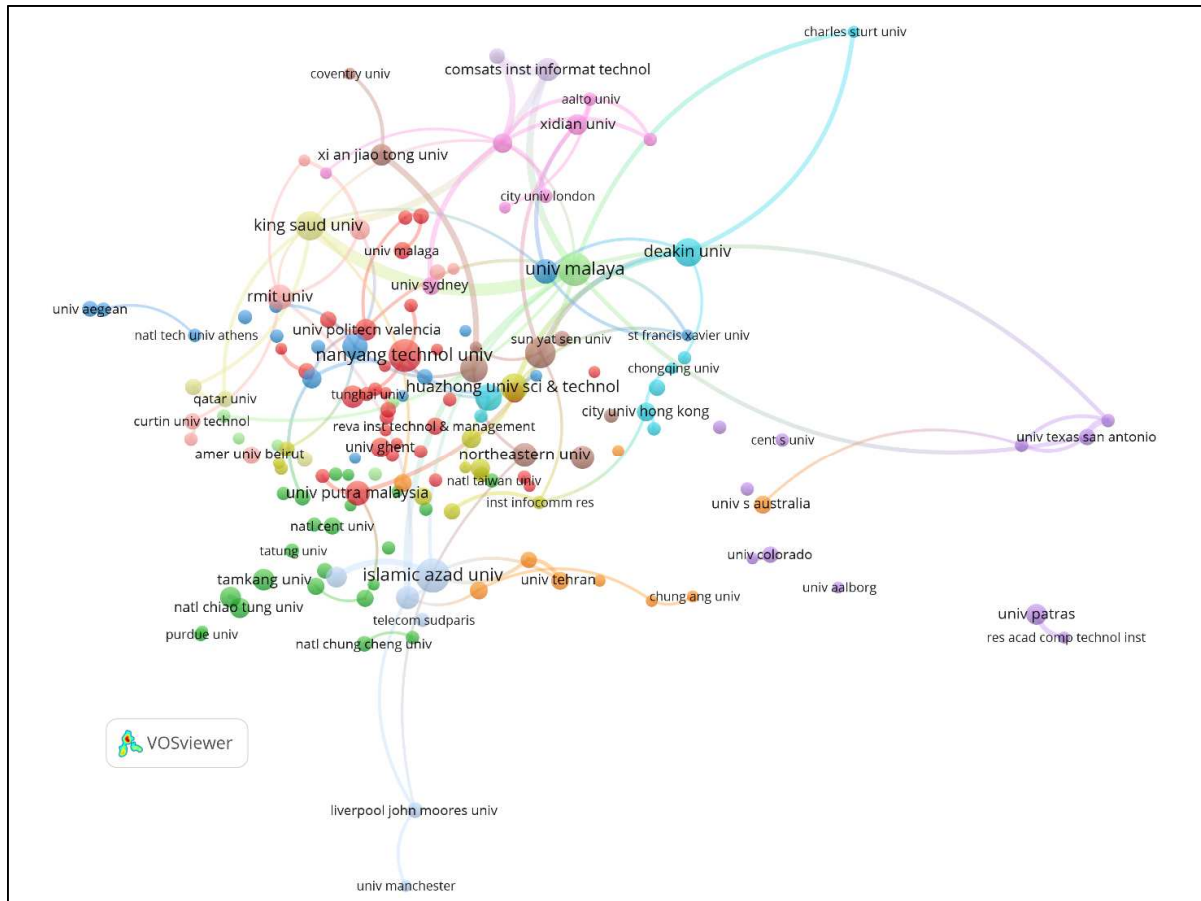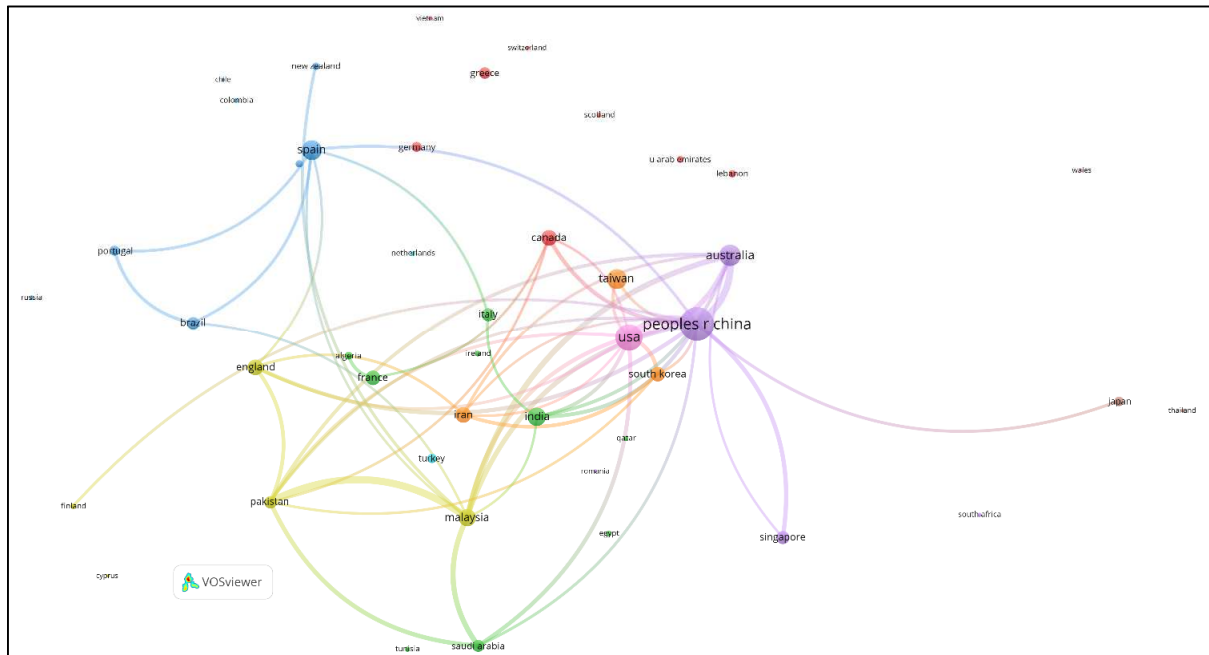
Fig. 7: Bibliographic coupling of institutions publishing in JNCA: minimum publication threshold of 5 documents and 100 links.

After co-citation analysis, let us examine the bibliographic coupling of institutions and countries [38-40]. Bibliographic coupling is the total number of times two entities have cited the same entity. It is basically the similarity relationship between the two nodes. Fig. 7 shows the bibliographic coupling of institutions publishing in JNCA where the minimum publication threshold is 5 documents and number of links between the nodes is 100. In terms of institutions, bibliographic coupling is the number of common papers they have cited together, or they have a reference list in common. The red-colored cluster includes Nanyang Technological University, University of Sydney, Tunghai University, Polytechnic University of Valencia, and Ghent University. The inclusion of institutions in this cluster implies that publications from these universities are citing the same references. The blue-colored cluster links institutions such as Deakin University, Charles Sturt University, Chongqing University, etc.

With respect to countries, two countries are bibliographically coupled when the papers published by them have common entries. The more common references they have, the more strongly coupled they are. Fig. 8 shows the bibliographic coupling of countries publishing in JNCA (minimum publication threshold=5 and links=50). The figure shows approximately 6-7 different colored clusters. The prominent ones are blue, yellow and purple. The blue-colored cluster comprises Spain, Portugal, Brazil and New Zealand. The yellow cluster includes

countries such as England, Finland, Pakistan, and Malaysia. People's Republic of China, Australia, Singapore, and Japan are included in the purple cluster.

Fig. 8: Bibliographic coupling of countries publishing in JNCA: Minimum publication threshold of 5 documents and 50 links.
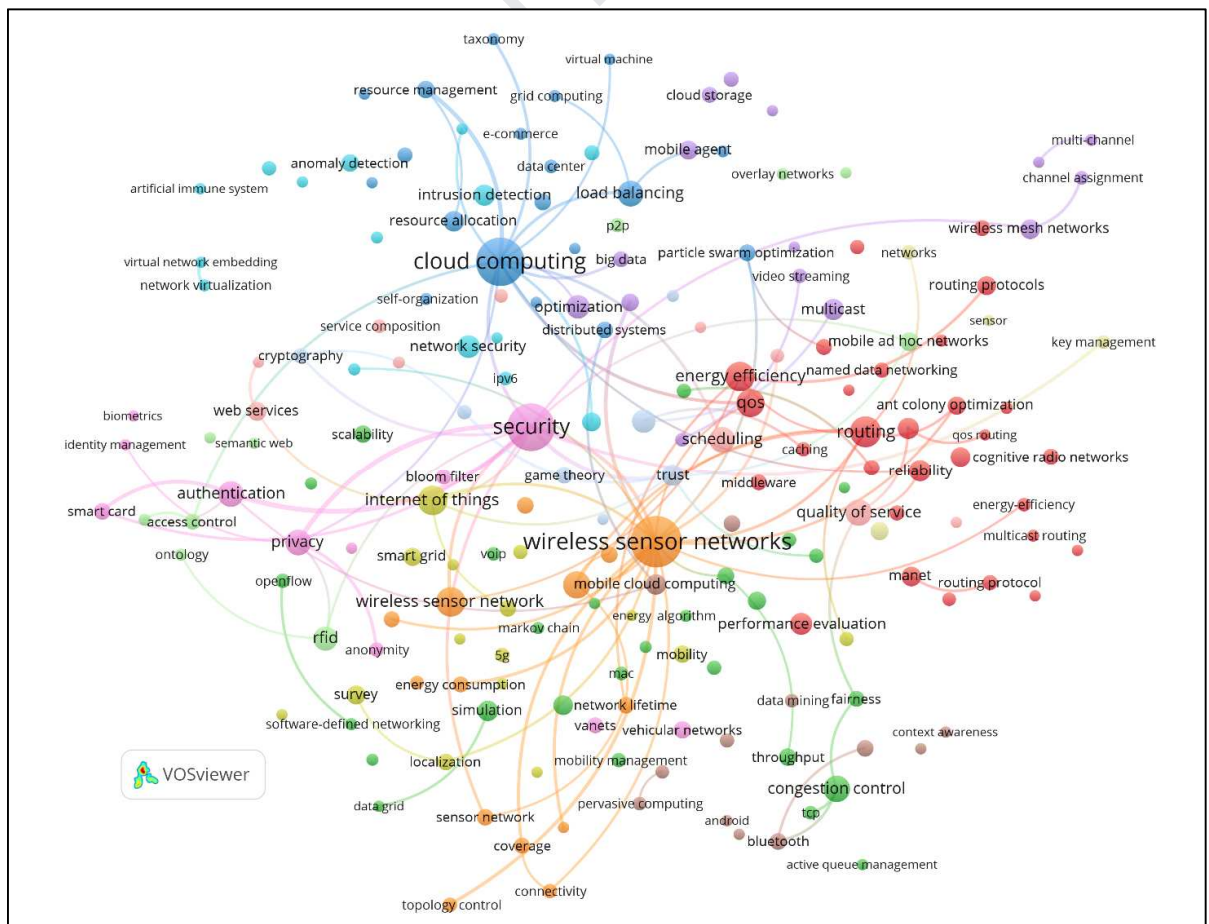
Fig. 9**:** Co-occurrence of author keywords in JNCA: minimum occurrence threshold of 3 and 100 links.

The next analysis is the co-occurrence of the authors' keywords [41-42] used in the JNCA publications. The co-occurrence is computed as the number of times two keywords appear together in publications. The keyword most in common is the largest node for that cluster. It can be visualized in Fig. 9, which shows the co-occurrence of author keywords in JNCA from 1997-2019 (minimum occurrence threshold=3 and links=100). Major nodes in the figures are Cloud Computing, Security, and Wireless sensor networks. If we start with the red-colored cluster, the keywords that occurred the most in many publications are: energy efficiency, QoS, routing, reliability, ant colony optimization, caching, etc. The orange cluster has wireless sensors networks, energy consumption, etc. Cloud computing, resource allocation, load balancing, resource management and e-commerce lie in the blue-colored cluster.
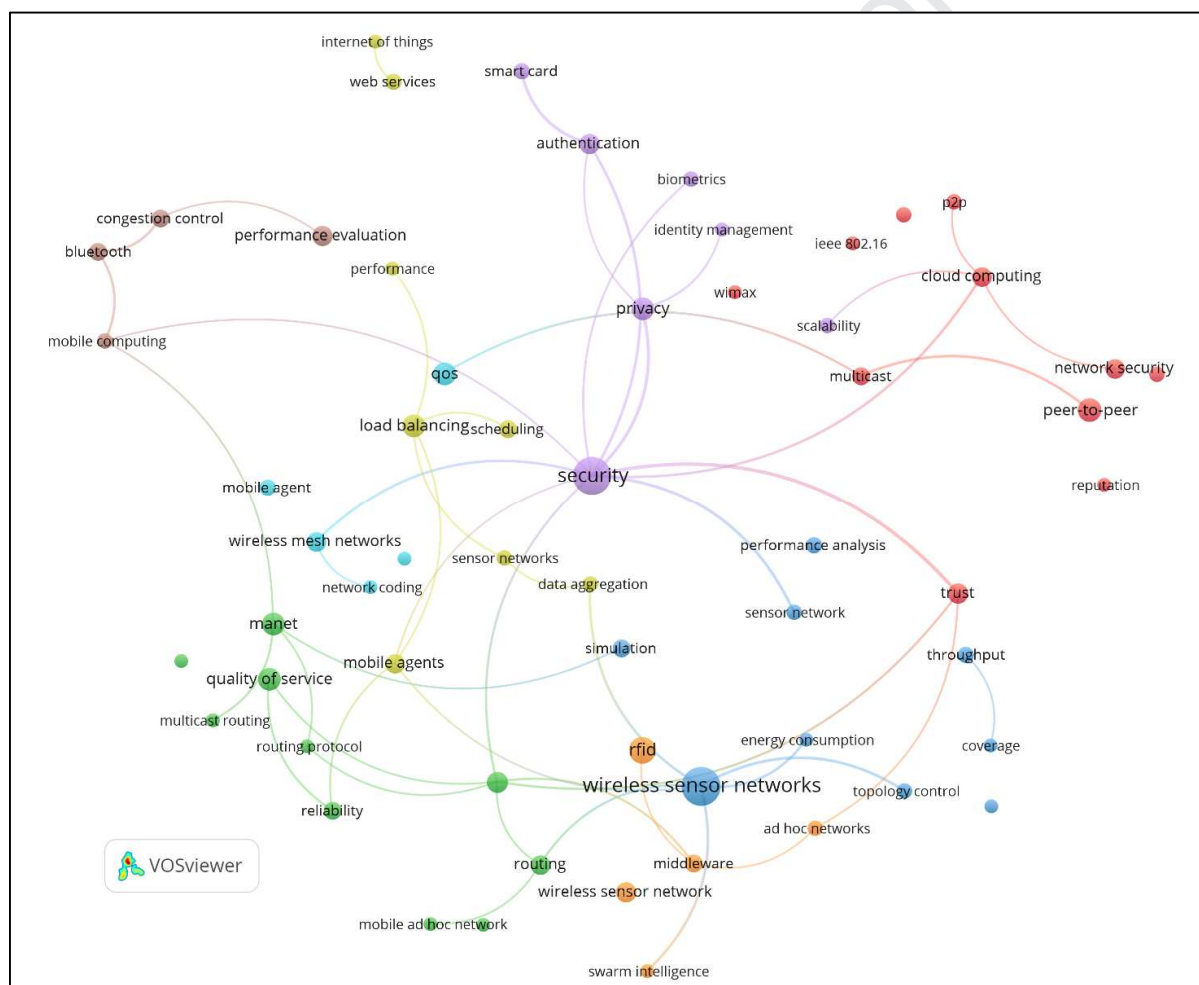
Fig. 10**:** Co-occurrence of author keywords in JNCA: 2008-2012 (minimum occurrence threshold of 2 and 100 links).

This keyword co-occurrence analysis is extended for the 2008-2012 and 2013-2019 periods in Figs. 10 and 11, respectively. In Fig. 10, the minimum occurrence threshold is 2 and number of links is 100. One of the prominent clusters is purple with the keywords security, privacy, authentication, smart card, etc. The blue cluster contains wireless sensor

networks, topology control, energy consumption, routing, etc. In Fig. 11, the minimum occurrence threshold is 10 and number of links is 100. The cluster with cloud computing as the largest node has keywords such as: optimization, mobile cloud computing, scheduling, load balancing and resource management. The light blue cluster links keywords such as energy efficiency, routing, networks, wireless, 5G, IoT, mobility and LTE.

The above discussion on VOSviewer visualization outcomes can be verified in Table 11, which has temporal and global analyses of keywords. It also contains author keyword occurrences (Oc) and author keyword co-occurrence links (Co). The top ranked keyword in this table is the largest node in the above figures.
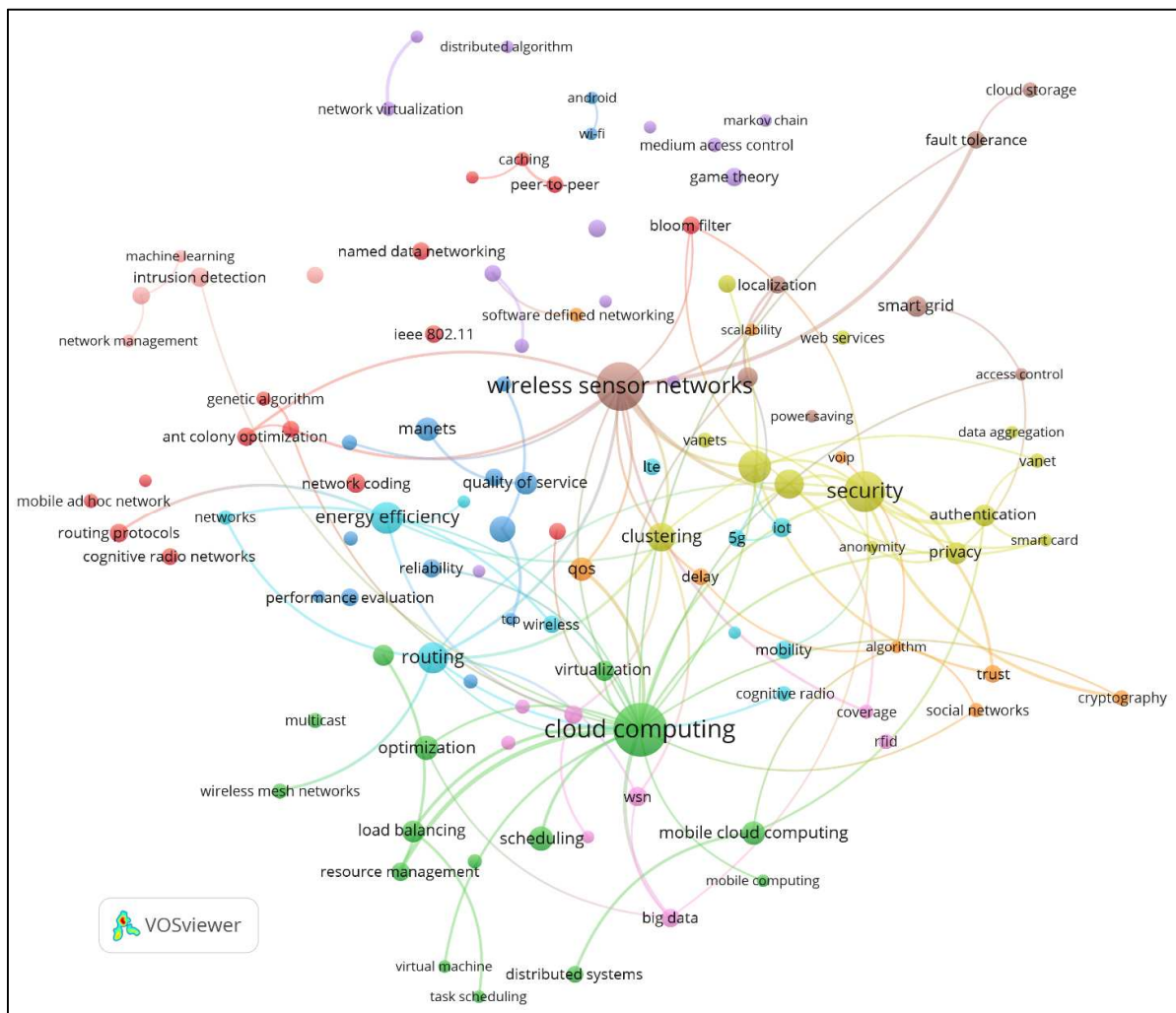
Fig. 11: Co-occurrence of author keywords in JNCA: 2013-2019 (minimum occurrence threshold of 10 and 100 links).

Table 11: Most common author keyword occurrences in JNCA.

	Global			2013-2019			2008-2012			1997-2007		
R	Keyword	Oc	Co	Keyword	Oc	Co	Keyword	Oc	Co	Keyword	Oc	Co
1	Wireless Sensor Networks	100	66	Cloud Computing	82	46	Wireless Sensor Networks	33	17	Mobile Agent	7	5
2	Cloud Computing	90	59	Wireless Sensor Networks	67	36	Security	31	26	Security	6	3
3	Security	85	75	Security	48	37	RFID	15	5	Agent	4	2
4	Routing	37	33	Energy Efficiency	30	17	Peer-To-Peer	12	4	Intrusion Detection	4	4
5	Internet of Things	34	20	Internet of Things	30	15	Load Balancing	11	4	Network Security	4	3
6	Wireless Sensor Network	34	21	Routing	27	23	Manet	11	6	Structural Computing	4	1
7	Energy Efficiency	33	19	Wireless Sensor Network	25	16	Privacy	11	8	Admission Control	3	1
8	QOS	30	24	Clustering	23	17	QOS	11	8	Authorization	3	3
9	Clustering	28	22	Congestion Control	20	11	Quality of Service	11	6	Intelligent Agents	3	0
10	Congestion Control	27	15	Optimization	17	12	Mobile Ad Hoc Networks	10	9	Multicast	3	1
11	Quality of Service	27	20	Scheduling	17	12	Authentication	9	7	QOS	3	1
12	Load Balancing	26	17	Manets	16	7	Performance Evaluation	9	3	Quality of Service (QOS)	3	1
13	Privacy	26	24	Mobile Cloud Computing	16	9	Trust	9	8	Search Engine	3	2
14	Authentication	25	22	QOS	16	13	Wireless Sensor Network	9	3	Access Control	2	2
15	Scheduling	25	20	Authentication	15	11	Cloud Computing	8	5	Advanced Encryption Standard	2	2
16	RFID	22	12	Quality of Service	15	10	Mobile Agents	8	4	Clustering	2	1
17	Optimization	21	16	Load Balancing	14	10	Network Security	8	3	CSCL	2	1
18	Peer-To-Peer	21	12	Privacy	14	12	Routing	8	6	Data Mining	2	2
19	Network Security	20	11	Resource Allocation	13	10	Wireless Mesh Networks	8	5	Digital Signature	2	1
20	Performance Evaluation	19	11	Smart Grid	13	7	Bluetooth	7	4	Distributed System	2	2
21	Reliability	18	14	Survey	12	8	Congestion Control	7	3	E-Commerce	2	2
22	Trust	18	18	Virtualization	12	10	Middleware	7	4	Features	2	0
23	Intrusion Detection	17	12	Intrusion Detection	11	4	Multicast	7	6	FPGA	2	0
24	Manets	17	10	IoT	11	9	Reliability	7	4	Genetic Algorithm	2	1
25	Multicast	17	13	Network Coding	11	7	Scheduling	7	5	Group Communication	2	2
26	Mobile Cloud Computing	16	10	WSN	11	8	Simulation	7	3	Hypermedia	2	1
27	Resource Allocation	16	12	Ant Colony Optimization	10	7	Mobile Agent	6	1	Information Retrieval	2	2
28	Simulation	16	12	Big Data	10	7	Performance Analysis	6	4	Information Sharing	2	0
29	Manet	15	10	Game Theory	10	4	Smart Card	6	5	Internet	2	1
30	Network Coding	15	10	Mobility	10	6	Throughput	6	2	Internetworking	2	0
31	Performance Analysis	15	11	Network Lifetime	10	9	Web Services	6	3	Multi-Agent	2	2
32	Wireless Mesh Networks	15	13	Reliability	10	9	Ad Hoc Networks	5	2	Multimedia	2	0
33	Mobile Ad Hoc Networks	14	11	Resource Management	10	9	Biometrics	5	3	Multimedia Adaptation	2	1
34	Mobile Agent	14	7	Routing Protocols	10	5	Data Aggregation	5	4	Network Management	2	2
35	Routing Protocols	14	8	Anomaly Detection	9	3	Mobile Computing	5	4	Network Services	2	2
36	Survey	14	9	Bloom Filter	9	5	P2P	5	2	Peer-To-Peer (P2P) Systems	2	1
37	Virtualization	14	13	Fault Tolerance	9	8	Scalability	5	3	Pervasive Computing	2	1
38	Web Services	14	11	IEEE 802.11	9	7	Sensor Network	5	4	Reinforcement Learning	2	2
39	Ant Colony Optimization	13	12	Localization	9	7	Sensor Networks	5	4	Routing	2	1
40	Smart Grid	13	7	Named Data Networking	9	5	Topology Control	5	4	Scalability	2	1

Abbreviations: R = Rank; Oc = Author keyword occurrences; Co = Author keyword co-occurrence links.

5. Conclusions

This is the first paper to develop a bibliometric analysis of the Journal of Network and Computer Applications (JNCA) from 1997-2019. JNCA is one of the leading journals in the computer science domain, having one of the highest impact factors in this field. During this period, a total of 2,349 papers have been published. They have received a total citation of 38,611.

The 2011 publication "A survey on security issues in service delivery models of cloud computing" from Subashini and Kavitha is the most influential paper with 990 citations. All of the papers in the top 10 highly cited papers were published within the last 10 years. Gani and Buyya from University of Malaya and University of Melbourne are the most influential authors in JNCA with total citations of 1,136 and 923, respectively. In terms of productivity, Yu, S tops the list with 25 publications. The top two influential universities are University of Malaya, Malaysia (TC=1,774) and Islamic Azad University, Iran (TC=1,316). However, the most productive university is Islamic Azad University with 49 papers. With respect to countries, People's Republic of China tops the list of most productive and influential countries (TP=733, TC=10,938).

With the help of the visualization tool VOSviewer, we have performed co-citation analysis of the journals citing JNCA. JNCA received the highest citations in the period of 2013-2019. However, Lecture Notes in Computer Science was the most cited source in 2008-2012, and in 1997-2007, Communications of the ACM was the most cited journal. In the bibliographic coupling of the institutions, Nanyang Technological University and University of Malaya are the most prominent nodes. In country-wise bibliographic coupling, People's Republic of China, USA, Spain, and India are a few of the largest nodes in their clusters. For the co-occurrence analysis of the author keywords, "Wireless Sensors Networks" received the highest author keyword occurrence in the time period of 2008-2012. "Mobile agent" was at the top during 1997-2007, and "Cloud Computing" had the highest occurrence in 2013-2019.

This work provides a general overview of the leading trends occurring in JNCA between 1997 and 2019. This is a useful approach for obtaining a quick snapshot of how the journal is performing over time. However, it is worth noting some limitations. First, the work uses the WoS Core Collection database, so all of the limitations of this database apply to this study. For example, WoS uses full counting, which gives more importance to those papers written by several coauthors because it gives one unit to each coauthor of the paper. To partially solve this limitation, in the graphical analysis with VOS viewer, the work considers fractional counting, always giving one unit to each paper and fractioning the results according to the number of coauthors. Finally, note that the work considers the results up to 2019. Therefore, the results provide an overview of the trends in the journal until this year. However, this data is dynamic in time and may evolve in different directions in the future.

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<u>Conflict of interest statement</u>

The authors declare that they do not have any conflict of interest statement.