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Wireless Sensor Networks Research Output in India from Scopus Database between 2010 and 2019 : A Scientometric Analysis

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Abstract

This study aim to scientometric analysis of wireless sensor networks research output in India from 2010 to 2019 and the data has been collected from Scopus online database with 11775 research publications. During the study period it is identified that, maximum number of 2058(17.48%) publications are contributed in the year 2019 and compound annual growth rate is 5.44. This study identified that, relative growth rate is 0.88 in the year 2011 and 0.19 in the year 2019. At the same doubling time found that 3.61 in the year 2019 and 0.78 in the year 2011. This study confirmed that, relative growth rate is decreasing trend and doubling time is increasing trend. During the study period average degree of collaboration is 0.96, range of collaborative co-efficient is (0.60 – 0.56), range of collaborative index is (2.89 – 2.56) and CAI is decreasing trend for more than three authors from 1st block year (106.71) to 2nd block year (97.39). During the study period, most contributing author is Das A.K., Anna University Chennai with 557(24.56%) publications, International journal of applied engineering research contributed maximum number of 461(20.21%) publications and United States of America produced maximum of 251(23.61%) research publications. The estimated growth of publications based on time series analysis statistical application will be expected in the year 2025 is around are equal to 2277 publications and the year 2030 is around are equal to 2827 publications. This study identified that, highly cited publications is Ojha, T., et.al.(2015)Wireless sensor networks for agriculture: The state-of-the-art in practice and future challenges, Computers and Electronics in Agriculture,118,66-84 and it is received maximum of 391 citations.

Keyword: Scientometric, Wireless Sensor Networks, Relative Growth Rate, Co-author Index, Degree of Collaboration, Relative Citation Index, Collaborative Index, Collaborative Co-efficient, Time series analysis.

Introduction

Wireless sensor networks can perform an important role in many applications, such as patient health monitoring, environmental observation and building intrusion surveillance. A Wireless Sensor Network is composed of a large number of sensor nodes and a base station. A base station is typically a gateway to another network, a powerful data processing or storage center, or an access point for human interfaces. It can be used as a connection to disseminate control information into the network or extract data from it. A base station is also referred to as a sink (1). Sinks are often many orders of magnitude more powerful than sensor nodes. The sensor nodes are usually scattered in a sensor field and each of these scattered sensor nodes has the capability to collect data and route data back to a sink and end users. The sink may communicate with the task manager node via the internet or via satellite communications (2).

A Wireless Sensor Network might consist of different types of sensor node such as low sampling rate magnetic, thermal, visual, infrared, and acoustic or radar sensors, which are able to monitor a wide variety of ambient conditions (3). **Crossbow** was one of the first suppliers of the Berkeley-style MICA **sensor nodes** that it **called** "**motes**". These run the TinyOS operating system and shows a design from sun micro systems, called a sun SPOT (small programmable object technology). Security is always an issue in traditional networks and brings increasing challenges over time. Wireless sensor networks have some additional issues as compared to traditional networks. For example cryptography requires complex processing to provide encryption of transmitted data. Secure routing; secure discovery and verification of location, key establishment and trust setup, and attacks against sensor nodes, secure group management and secure data aggregation are some of the many issues that need to be addressed in a security context. (4).

As described earlier, a sensor node is a tiny device, with only a small amount of memory and storage space for the code. In order to build an effective security mechanism, it is necessary to limit the code size of the security algorithm. For example, one common sensor type (TelosB) has a 16-bit, 8MHz RISC CPU with only 4–10K RAM, 48K program memory, and 1024K flash storage (5).With such limitations the software built for the sensor node must also be quite small. Therefore, the code size for all security-related code must also be small. Security also becomes more challenging when we talk about scalable WSNs or add considerations of mobility to the WSN. It has been identified that even the network topology can directly affect security (6). All of these issues are inter-linked with one another, making them even more challenging.

Scientometric Study

Karisiddappa, Maheswarappa and Shirol (1990).[7] studied the authorship pattern and collaborative research in psychology research publications. Bakri and Willett (2008)[8] studied the range of articles published per volume, average number of references per article, the average length per article pages, percentage of multi authored papers, geographically affiliation. Amsaveni and Vasanthi (2013)[9] suggested the trend in authorship pattern and collaborative research in network security during 2002 to 2011 was measured. Thavamani and Velmurugan (2013)[10] studied the analysis has been conducted with 310 contributions published in the journal during the year 2002 – 2012. Jena, Kamal Lochan (2006)[11] traced the trend of publications such as the year wise distribution of articles, bibliographical distribution of citations, authorship pattern, citation pattern, average length of articles, geographical distribution of authors have been studied. Vimala and Pulla Reddy (2009)[12] derived authorship pattern and collaborative research in zoology. Zafrunnisha and Pulla Reddy (2009)[13] studied authorship trend and collaborative authorship pattern and collaborative research in the field of Psychology.

Review of Literature

Ravichandran and Vivekanandhan (2020)[14] analyzed the solid waste management research publications (2010-2019) using SCOPUS database with 5198 research publications. The study identified that, maximum of 694 (13.35%) research publications in the year 2019, CAGR was 3.67. Maximum of 3907(75.16%) research publications are contributed by article, maximum of 43 (0.83%) research publications are contributed by Huang G.H, India. During the study identified that multi authors are dominated in this study field and average degree of collaboration was 0.88. Relative growth rate was 0.63 in the year 2011 and 0.14 in the year 2019 at the same time doubling time was 1.10 in the year 2011 and 4.84 in the year 2019.

Velmurugan and Radhakrishnan (2017)[15] examined the scholarly research publications on Nephrology from Indian scientists during 2010-2015 from Web of Science database. The study identified that, total number of 2622 publications with 11993 citations were found during the analysis and focus the various bibliographic forms of Nephrology literature include articles, reviews, article based proceedings papers and editorial materials. The study analyzed authorship pattern, single versus multi-authored research publications, ranking of core journals, documents and geographical wise distribution.

Suradkar and Dayadalve (2016)[16] identified the trends in authorship pattern and authors collaborative research in *Academic Emergency Medicine Journal* with 3586 articles during the period of 2001-2013. The study reveals that the major publications are contributed by multiple authors. The degree of collaboration was progressively increased over the span of the study period.

Natarajan and Kaliyaperumal (2016)[17] carried out the research progress on collaborative research was predominant among the science discipline. The study identified most of the different countries authors are collaborated with the authors of United Sates of America. The study identified that the majority of the Indian scientists collaborated with the authors of United Sates of American authors, Japan and South Korea.

Thavamani (2015)[18] analysis the authorship pattern of *collaborative librarianship* during 2009-2014 among 343 authors are contributed 223 research papers. The study carried out 1.538 is the mean number of author productivity. The average degree of collaboration was 0.354 and the productivity of author was 0.650.

Rajendran et al., (2013)[19] examine the Indian research publications in wireless communication research during 2001-2012 from the SCOPUS database with 1128 publications. The study analysis the Scientometrics tools such as, relative growth rate and doubling time, degree of collaboration and co-authorship index have been analyzed. Further, they identified top 10 most preferred journals, type of document and highly productive Indian institutions.

Vivekanandhan et al., (2016)[20] examined the pollution control research contributions in India from Scopus database during 2003-2014 with 28445 research publications, India was placing 3rd with 1551 research publications. Further, they analyzed the country wise research publications, and share of Indian publications with citations, type of documents and publication efficiency index.

Ravichandran.S & Vivekanandhan. S (2021)[21] examine the Scientometric analysis of waste water management research publications during the period of 2010-2019 from the Scopus online database. This study identified that maximum of 2842(14.31%) research publications with 19857 citations are contributed in the year 2019. Ngo, H.H, contributed a maximum of 101 (0.51%) research publications, maximum of 19355 articles were contributed by joint authors and average degree of collaboration was 0.97. The range of Collaborative Co-efficient was (0.76-0.69), and the range of Collaborative index was (4.85-4.09). Maximum of 2102(10.58%) research publications are contributed in Bio resource technology, the ministry of education, china with 863(22.32%) research publication and China has contributed maximum of 5919(29.80%) research publications. Maximum of 18037 (90.82%) research publications are contributed by article.

Objective of the Study

- To study the year wise growth of Wireless Sensor Network reseaech publications in India
- To examine the relative growth rate and doubling time.
- To study the authorship pattern.
- To study the degree of collaboration, CC and CI
- To findout the co-authorship index.
- To identify the top 10 Authors, Institutions, Journals
- To identify the International Collaborated Countries in India
- To examine the time series analysis
- To identify the top 10 keywords and top 10 funding agencies
- To identify the top 10 highly cited publications in India

Research method

This study identified the wireless sensor network research publications using Scopus multidisciplinary online database from 2010 to 2019. The following search keyword is used to collect the data. The search key is : (TITLE-ABS-KEY ("Wireless Sensor Network") AND PUBYEAR > 2009 AND PUBYEAR < 2020 AND (LIMIT-TO (AFFILCOUNTRY,"India”))) The data was collected for this study is 23.12.2020. The collected data’s were analyzed using Micro Soft Excel work sheet.

Data Analysis and Interpretations

Year Wise Growth of Wireless Sensor Network Research Outputs

Table 1 Year Wise Growth of Publications

S.No	Year	No of Publications	%	Cum.	%
1	2010	378	3.21	378	0.77

2	2011	537	4.56	915	1.87
3	2012	625	5.31	1540	3.15
4	2013	716	6.08	2256	4.61
5	2014	1044	8.87	3300	6.75
6	2015	1464	12.43	4764	9.74
7	2016	1644	13.96	6408	13.10
8	2017	1463	12.42	7871	16.09
9	2018	1846	15.68	9717	19.86
10	2019	2058	17.48	11775	24.07
	Total	11775	100.00	48924	100.00
	CAGR	5.44			

Table 1 identify the year wise growth of wireless sensor network research outputs in India between the year 2010 and 2019 from the Scopus online database with 11775 records. During the study period it is identified that, maximum number of 2058(17.48%) publications in the year 2019. Followed by the year 2018 has contributed 1846(15.68%) publications, the year 2016 with 1644(13.96%) publications.

Compound Annual Growth Rate [CAGR]

The Compound Annual Growth Rate [CAGR] is one of the useful measures to identify the growth, over the multiple time periods. It can be measure from the initial number of publications to ending number of publications. The mathematical formula of CAGR is used Ashok Kumar and Gopala Krishnan (2013)[22]

The compound annual growth rate was calculated by the following formula,

$$\mathbf{CAGR} = \left[\frac{\mathbf{Ending\ Value}}{\mathbf{Begining\ Value}}\right]^{\left[\frac{1}{\#\ \mathbf{of\ Years}}\right]} - 1$$

During the ten year study period compound annual growth rate is calculated by the wireless sensor network research outputs in India from the beginning year and ending year. It is identified from the table 1 the compound annual growth rate is 5.44.

Relative Growth Rate (RGR)

The most important feature of science and technology in recent years has been calculated by the rate of growth. Scientific growth has been involved not only increase in manpower and financial investment. The relative growth rate is identified by the increase in number of publications per unit of time. The mean relative growth rate over the particular period of interval can be calculated in the following formula developed by Mahapatra (1985)[23]

$$\mathrm{R(a)} = \frac{(W_2 - W_1)}{(\mathrm{T_2} - \mathrm{T_1})}$$

Where,
R (a) = RGR = the mean relative growth rate over the specific period of interval
W_1 = the logarithm of beginning number of publications/pages
W_2= the logarithm of ending number of publications/pages after a specific period of interval
$T_2 – T_1$ = the unit difference between the beginning time and the ending time.

The doubling time is the time taken for the doubling of the number of records actually published within a stipulated period. The doubling time is calculated from the relative growth rate and the natural logarithm number is used, the difference has a value of 0.693. The corresponding doubling time can be calculated by the following formula,

$$\mathrm{Dt} = \frac{0.693}{\mathrm{R(a)}}$$

Relative Growth Rate and Doubling Time in Wireless Sensor Network Research Outputs

Table 2 Relative Growth Rate and Doubling Time

Sl.No	Year	No of Publications	Cum.	W_1	W_2	RGR=(W_2-W_1)	Dt=(0.693/RGR)
1	2010	378	378		5.93		
2	2011	537	915	5.93	6.82	0.88	0.78
3	2012	625	1540	6.82	7.34	0.52	1.33
4	2013	716	2256	7.34	7.72	0.38	1.82
5	2014	1044	3300	7.72	8.10	0.38	1.82
6	2015	1464	4764	8.10	8.47	0.37	1.89
7	2016	1644	6408	8.47	8.77	0.30	2.34
8	2017	1463	7871	8.77	8.97	0.21	3.37
9	2018	1846	9717	8.97	9.18	0.21	3.29
10	2019	2058	11775	9.18	9.37	0.19	3.61
Total		11775		71.30	80.68	3.44	20.24

The relative growth rate and the doubling time (Dt) in wireless sensor network research output in India is calculate and the results are presented in table 2. From the study it is identified that, the relative growth rate is 0.88 in the year 2011 and 0.19 in the year 2019. This study confirmed that, relative growth rate is decreasing trend from 2011 to 2019. At the same time, doubling time is found that 0.78 in the year 2011 and 3.61 in the year 2019. It is conformed that doubling time is increasing trend during the study period.

Authorship Pattern in Wireless Sensor Network Research Outputs

Table 3 Authorship Pattern

Sl.No	Authorship Pattern	No of Publications	%	Rank
1	One	428	3.63	5
2	Two	5911	50.20	1
3	Three	3393	28.82	2
4	Four	1272	10.80	3
5	Five	471	4.00	4
6	Six	206	1.75	6
7	Seven	56	0.48	7
8	Eight	18	0.15	8
9	Nine	6	0.05	10
10	**Ten and above**	14	0.12	9
Total		11775	100.00	

Table 3 indicates the authorship pattern in the field of wireless sensor network research output in India for the selected ten year study period. From the study it is identified from the table-3, majority of the authors in the field are preferred to publish their research works in two authorship mode with 5911(50.20 %) publications. Followed by three authorship mode with 3393(28.82 %) publications, four authorship mode with 1272(10.80 %) publications. During the study period single authors are contributed only 428(3.63 %) publications. More than nine authors are contributed only 14(0.12%) publications. This study conformed that more than 95% of publications are contributed in multiple authors.

Degree of Collaboration

Degree of collaboration is relationship between the single author and multi authors contributions. The degree of collaboration is calculated by the Subramanian formula (1983)[24], used by Vivekanandhan (2016), [25] Sivasamy (2020).[26] Ravichandran (2021)[21]

$$DC = \frac{Nm}{(Nm + Ns)}$$

Where DC = Degree of Collaboration

N_m = Number of multi authored publications

N_s = Number of single authored publications

In the present study, Nm = 11347, Ns= 428

So that, the degree of collaboration is =11347/ (428+11347) = 0.96

Table 4 Degree of Collaboration

Year	Single Author Publications	Multi Author Publications	Total No of Publications	Degree of Collaboration DC= $N_M/(N_M+N_S)$
2010	16	362	378	0.96
2011	14	523	537	0.97
2012	21	604	625	0.97
2013	21	695	716	0.97
2014	42	1002	1044	0.96
2015	69	1395	1464	0.95
2016	72	1572	1644	0.96
2017	51	1412	1463	0.97
2018	59	1787	1846	0.97
2019	63	1995	2058	0.97
Total	**428**	**11347**	**11775**	**0.96**

Table 4 shows that, degree of collaboration in wireless sensor network research publications in India for the selected ten year studies period. From this study it is identified that, the degree of collaboration is between 0.96 in the year 2010 and 0.97 in the year 2019. The average degree of collaboration is 0.96. From this study it is identified that, majority of wireless sensor network research publications are contributed by collaborative authors.

Collaborative Coefficient (CC)

The pattern of co-authorship collaboration among the authors can be measured with the following formula suggested by Ajiferuke, et al. (1988)[27]

$$CC = 1 - \left[\sum_{j=0}^{k} \left(\frac{1}{j}\right) \times Fj/N\right]$$

Whereas,

Fj = Number of publications with j author papers

N = Total number of the research publications and

k = the greatest number of authors/ paper in the given field.

Collaboration Index (CI)

The simple indicator are presently employed in the publications to the collaboration index, which is to be understand nearly as the mean number of authors per paper are suggested by Ajiferuke, et al.(1988)[27]

$$CI = \frac{\sum_{j=1}^{k} jfj}{N}$$

Here

J - The number of co-authored papers appearing in a discipline

N - The total number of publications in the field over the same time period of interval and

k - The highest number of authors per paper in a same time field.

Collaborative Index, Collaborative Co-efficient in Wireless Sensor Network Research Publications

Table 5 Collaborative Measures

Year	1	2	3	4	5	6	7	8	9	10	CC	CI	Total
2010	16	147	130	48	25	10	1	1	0	0	0.60	2.89	378
2011	14	244	163	67	36	8	3	0	1	1	0.60	2.84	537
2012	21	270	194	90	28	14	5	1	1	1	0.60	2.86	625
2013	21	353	225	71	33	9	3	1	0	0	0.58	2.70	716
2014	42	531	318	96	30	23	2	2	0	0	0.57	2.64	1044
2015	69	809	398	121	37	19	7	2	0	2	0.56	2.56	1464
2016	72	873	454	164	46	23	6	1	2	3	0.56	2.62	1644
2017	51	756	391	168	64	20	8	1	1	3	0.58	2.70	1463
2018	59	919	519	220	78	35	7	6	1	2	0.58	2.74	1846
2019	63	1009	601	227	94	45	14	3	0	2	0.59	2.76	2058
Total	428	5911	3393	1272	471	206	56	18	6	14	0.58	2.70	11775

Table 5 shows that, collaborative measures of wireless sensor network research publications in India for the selected ten year study period from 2010 to 2019. From the studt it is identified that, It is identified from the table 7, maximum of collaboration value is 0.60 in the year 2010, 2011 and 2012, and mimimum of collaborative coefficient value is 0.57 in the year 2014. The average collaborative coefficient value is 0.58. The collaboration index values are identified from the table 7, maximum of collaboration index value is 2.89 in the year 2010 and minimum of collaboration index value is 2.56 in the year 2015. During the study period the average collaboration index value is 2.70.

Co-authorship Index (CAI)

To study how the pattern of co-authorship and the use of co-authorship index suggested by Garg and Padhi (2001)[28] has been explained the under mentioned formula. To evaluate the co-authorship index (CAI) is the whole set of data is divided into 2 block years.

$$CAI = \left[\frac{(Nij/Nio)}{(Noj/Noo)}\right] \times 100$$

Where as,

Nij - Number of publications having j authors in i block

Nio - Total publications of i block

Noj - Number of publications having j authors for all blocks

Noo-: Total number of publications for all authors and the all blocks

Here CAI=100 implies that a country's co-authorship effort for a particular authorship correspond to the world average

CAI > 100 reflects higher than average co-authorship effort

CAI < 100 reflects lower than average co-authorship effort by the given type of authorship pattern.

For calculating the co-authorship index for authors, years have been replaced into block years. For this study, the authors have been classified into two blocks (ie.2010-2014 and 2015-2019) Vs**.** Single, Two, Three authors and More than 3 authors.

Co- Authorship Index (CAI) in wireless sensor network

Table 6 Co- Authorship Index

Block Years	**Single Author**	**CAI**	**Two Authors**	**CAI**	**Three Authors**	**CAI**	**More Than Three Authors**	**CAI**	**Total No of Publications**
2010-2014	114	95.04	1545	93.26	1030	108.32	611	106.71	3300
2015-2019	314	101.93	4366	102.62	2363	96.76	1432	97.39	8475
Total	**428**		**5911**		**3393**		**2043**		**11775**

Table 6 shows that, Co-Authorship Index values are calculated by the block year period for wireless sensor network research publications in India for the selected ten year study period. From the study it is identified that, CAI for single and two authorship contributions are

increasing trend from 1st block year to 2nd block year. At the same time CAI is decreasing trend for three authors and more than three authors from 1st block year to 2nd block years.

Relative Citation Index (RCI)

Relative citation index (RCI) was developed by the Institute of Scientific Information and examine the impact of different countries, institutions, authors and journals research publications. The scientific impact of leading countries was examined by using two relative indicators, namely citations per paper (CPP) and relative citations index (RCI). Citations per paper (CPP) are a relative indicator computed as the average number of citation per paper. To measure the both influence and visibility of a country research, the following formula has been used by Bharvi Dutt and Khaiser Nikam (2016)[29]

$$\text{RCI} = \frac{\text{A Country share of the World Citations}}{\text{A Country share of the World Publications}}$$

RCI = 1 indicate that a country's citation rate is equal to the world citation rate
RCI > 1 indicate that a country's citation rate is greater than the world citation rate
RCI < 1 indicate that a country's citation rate is lower than the world citation rate

Top 10 Authors Contribution in Wireless Sensor Network Research Publications in India

Table 7 Top 10 Authors Contribution

S.No	Name of the Author	Country	No of Publications	%	No of Citations	%	CPP	h-index	RCI
1	Das, A.K.	India	82	15.36	1781	26.15	21.72	22	1.70
2	Misra, S.	United States of America	66	12.36	2021	29.68	30.62	23	2.40
3	Kumar, N.	China	64	11.99	161	2.36	2.52	5	0.20
4	Jana, P.K.	South Korea	55	10.30	356	5.23	6.47	10	0.51
5	Obaidat, M.S.	United Kingdom	48	8.99	154	2.26	3.21	5	0.25
6	Venugopal, K.R.	Australia	48	8.99	197	2.89	4.10	8	0.32
7	Kumari, S.	Saudi Arabia	47	8.80	474	6.96	10.09	12	0.79
8	Gupta, B.B.	Canada	43	8.05	581	8.53	13.51	12	1.06
9	Banerjee, I.	Singapore	41	7.68	413	6.06	10.07	12	0.79
10	Patnaik, L.M.	France	40	7.49	672	9.87	16.80	15	1.32
Total			534	100.00	6810	100.00			

Table 7 identified the top ten authors contribution in wireless sensor network research publications in India from SCOPUS database for the selected ten year study period. From the study it is identified that, maximum of 82(15.36%) research publications are contributed by Das, A.K., India and his publications are received 1781(26.15%) citations, CPP is 21.72, h-index is 22 and RCI value is 1.70. Followed by Misra, S from USA with 66(12.36%) research publications and it is received by 2021(29.68%) citations, CPP is 30.62, h-index is 23 and RCI value is 2.40. Third ranking author is Kumar, N from China with 64(11.99%) research publications, 161(2.36%) citations, CPP is 2.52, h-index is 5 and RCI value is 0.20. During the study period from the top ten authors, four authors RCI value is more than the world average and remaining six authors RCI value is below the world average.

Top 10 Institutions Contributions in Wireless Sensor Networks research output in India

Table 8 Top Ten Institutions Contributions

Sl. No	Name of the Institutions	No of Publications	%	No of Citations	%	CPP	h-index	RCI
1	Anna University	557	24.56	3097	16	6	21	0.63
2	Sathyabama Institute of Science and Technology	308	13.58	769	4	2	11	0.28
3	Vellore Institute of Technology, Vellore	292	12.87	2716	14	9	24	1.06
4	Jadavpur University	206	9.08	1652	8	8	18	0.91
5	Indian Institute of Science, Bengaluru	172	7.58	1447	7	8	17	0.96
6	Indian Institute of Technology Kharagpur	166	7.32	2832	14	17	26	1.94
7	K L Deemed to be University	145	6.39	388	2	3	9	0.30
8	Indian Institute of Technology, Indian School of Mines, Dhanbad	143	6.31	3178	16	22	29	2.53
9	Thapar Institute of Engineering & Technology	142	6.26	2533	13	18	25	2.03
10	National Institute of Technology Rourkela	137	6.04	1301	7	9	19	1.08
	Total	2268	100.00	19913	100			

It is identified from the table 8, top 10 institutions are contributed a total number of 2268 publications and it is received 19913 citations for the selected ten year study period in wireless sensor networks research output in India. From the study it is identified that, maximum number of 557(24.56%) publications are contributed by Anna University and it is received 3097(16%) citations, CPP is 6, h-index is 21 and RCI value is 0.63. Followed by Satyabhama Institute of Science and Technology contributed with 308(13.58%) research publications, 769(4%) citations, CPP is 2, h-index is 11 and RCI value is 0.28. Third rank institution is Vellore Institute of Technology, Vellore with 292(12.87%) research publications, 2716(14%) citations, CPP is 9, h-index is 24 and RCI value is 1.06.

During the ten year study period relative citation index values are identified that, maximum of RCI value is 2.53 for Indian Institute of Technology, Indian School of Mines, Dhanbad. Followed by RCI value is 2.03 for Thapar Institute of Engineering and AMP, Technology. From the study it is identified from the table 9, out of top ten institutions, 5 institutions RCI value is more than world average and remaining 5 institutions RCI value is below the world average.

Top Ten Journals Contributions in Wireless Sensor Networks Research Output in India

Table 9 Top Ten Journals Contributions

Sl. No	Name of the Journals	No of Publications	%	No of Citations	%	CPP	h-index	RCI
1	International Journal of Applied Engineering Research	461	20.21	245	2.99	0.53	6	0.15
2	Advances in Intelligent Systems and Computing	395	17.32	893	10.89	2.26	10	0.63
3	Wireless Personal Communications	322	14.12	2905	35.42	9.02	26	2.51
4	Communications in Computer and Information Science	234	10.26	983	11.98	4.20	10	1.17
5	International Journal of Innovative Technology and Exploring Engineering	175	7.67	149	1.82	0.85	4	0.24
6	Journal of Advanced Research in Dynamical and Control Systems	164	7.19	76	0.93	0.46	4	0.13
7	Procedia Computer Science	141	6.18	1573	19.18	11.16	19	3.10
8	International Journal of Recent Technology and Engineering	139	6.09	56	0.68	0.40	3	0.11
9	Lecture Notes in Computer Science Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics	127	5.57	582	7.10	4.58	11	1.27
10	Indian Journal of Science and Technology	123	5.39	740	9.02	6.02	13	1.67
Total		2281	100.00	8202	100.00			

Table 9 shows that, top10 journals contributions in the field of wireless sensor network research publications in India. From the study it is identified that, maximum of 461(20.21%) research publications are contributed by International Journal of Applied Engineering Research and it is received by 245(2.99%) citations, CPP is 0.53, h-index is 6 and RCI value is 0.15. Followed by Advances in Intelligent Systems and Computing with 395(17.32%) research publications, 893(10.89%) citations, CPP is 2.26, h-index is 10 and RCI value is 0.63. Third placed contributing journal is Wireless Personal Communications research with 322(14.12%) publications, 2905(35.42%) citations, CPP is 9.02, h-index is 26 and RCI value is 2.51. From the study RCI values are identified from the table 9, out of top ten journals, 5 journals RCI value is more than the world average and remaining 5 journals RCI value is below the world average.

International Collaborated Countries in Wireless Sensor Network Research Publications in India

Table 10 International Collaborated Countries

S.No	Country	No of Publications	Pub %
1	United States	251	23.61
2	China	86	8.09
3	South Korea	63	5.93
4	United Kingdom	60	5.64
5	Australia	58	5.46
6	Saudi Arabia	41	3.86
7	France	35	3.29
8	Canada	30	2.82
9	Singapore	27	2.54
10	Malaysia	26	2.45
Others country-61		386	36.31
Total		**1063**	**100.00**

Table 10 shows that, top 10 international collaborated countries in wireless sensor network research publications during the study period of 2010-2019. From this study it is identified that, maximum of 251(37.08%) research publications are collaborated by United States of America. Followed by China with 86(12.70%) research publications, South Korea with 63(9.31%) research publications. During the ten year study period total number of 1063 publications are collaborated by 71 countries.

Time Series Analysis in Wireless Sensor Network Research Publications in India

Table 11 Time Series Analysis

S.No	Year	No of Publications (Y)	X	X^2	XY
1	2010	378	-5	25	-1890

2	2011	537	-4	16	-2148
3	2012	625	-3	9	-1875
4	2013	716	-2	4	-1432
5	2014	1044	-1	1	-1044
6	2015	1463	1	1	1463
7	2016	1464	2	4	2928
8	2017	1644	3	9	4932
9	2018	1846	4	16	7384
10	2019	2058	5	25	10290
Total		11775		110	18608

Time series analysis study reveals that, the estimated growth values are identified based on previous data. A straight –line equation is adapted to measure the future values based on previous data. Time series analysis used by Jeyshankar (2013)[30] . This study identified the future prediction of wireless sensor network research publications in India for the year 2025 and 2030.

Straight Line Equation is

$Y = a + bx$

Here,

$\sum Y = 11775, \sum X^2 = 110, \sum XY = 18608$

$a = \sum Y/N = 11775/10 = 1177.5 = 1178$

$b = \sum XY/ \sum X^2 = 18608/110 = 169.16 = 169$

Estimate growth of publications in the year 2025 is, when x = 2025-2015 = 10

$Y = a + bx$

$= 1177 + (110*10) = 1177+1100 = 2277$

Estimated growth of publications in the year 2030 is, when x = 2030-2015 = 15

$Y = a + bx$

$= 1177 + (110*15) = 1177 + 1650 = 2827$

The estimated growth based on a time series analysis statistical application will be expected in the wireless sensor network research publications in Indian in the year 2025 is around are equal to 2277 publications and the year 2030 is around are equal to 2827 publications. So that time serious analysis study conformed wireless sensor network research publications in India is increasing trend.

Top Ten Keywords in Wireless Sensor Networks Research Publications in India

Table 12 Top Ten Keywords

S. No	Keyword	No of Frequency	%
1	Wireless Sensor Networks	7496	28.92
2	Sensor Nodes	5379	20.75
3	Energy Efficiency	2792	10.77
4	Wireless Sensor Network	2334	9.01
5	Energy Utilization	2121	8.18
6	WSN	1341	5.17
7	Wireless Sensor Network (WSNs)	1187	4.58
8	Power Management (telecommunication)	1121	4.33
9	Routing Protocols	1093	4.22
10	Network Lifetime	1053	4.06
Total		**25917**	**100.00**

Table- 12 deals with keyword analysis in wireless sensor networks research publications in India during the selected ten year study period. From this study it is identified that, top ten keywords are frequently used in the field of wireless sensor networks research activities into 25917 times. During the study period, Wireless Sensor Networks keywords are used in maximum number of 7496(28.92%) times. Followed by Sensor Nodes keywords are used into 5379(20.75%) times, Energy Efficiency keyword is used in 2792(10.77%) times. This study identified that top ten keywords are used in 25917 times for the selected ten year study period with a total number of 11775 publications.

Top 10 Funding Agency in Wireless Sensor Network Research Publications in India

Table 13 top 10 Funding Sponsor

S. No	Name of the Funding Agency	No of Frequency	%
1	Department of Science and Technology, Government of Kerala	51	22.27
2	National Natural Science Foundation of China	33	14.41

3	University Grants Commission	24	10.48
4	Department of Electronics and Information Technology, Ministry of Communications and Information Technology	22	9.61
5	Ministry of Electronics and Information technology	22	9.61
6	Science and Engineering Research Board	22	9.61
7	Department of Science and Technology, Ministry of Science and Technology, India	18	7.86
8	Ministry of Human Resource Development	16	6.99
9	National Science Foundation	12	5.24
10	Defense Research and Development Organization	9	3.93
Total		**229**	**100.00**

Table 13 deals with the top 10 funding agency in wireless sensor networks research publications in India for the selected ten year study period. During the study period it is identified that, total number of 229 research publications are sponsored for the top ten funding agencies in the field of wireless sensor networks research publications in India. This study identified that, maximum number of 51 (22.27%) research publications are sponsored by Department of Science and Technology, Government of Kerala. Followed by National Natural Science foundation of China has sponsored 33(14.41%) research publications, University Grants Commission with 24(10.48%) research publications.

Top 10 Highly Cited Wireless Sensor Network Research Publications in India

Table- 14 Top 10 Highly Cited Publications

S.No	Details of the Publication	Citations	Document
1	Ojha, T., et.al.(2015)Wireless sensor networks for agriculture: The state-of-the-art in practice and future challenges, Computers and Electronics in Agriculture,118,66-84.	391	Review
2	Kuila, P., et.al (2014) Energy efficient clustering and routing algorithms for wireless sensor networks: Particle swarm optimization approach, Engineering Applications of Artificial Intelligence, 33. 127-140	318	Article
3	Tyagi, S., et.al(2013)A systematic review on clustering and routing techniques based upon LEACH protocol for wireless sensor networks, Journal of Network and Computer Applications, 36(2), 362-645	301	Review
4	Nayak, P., et.al(2016)A Fuzzy Logic-Based Clustering Algorithm for WSN to Extend the Network Lifetime, IEEE Sensors Journal, 16(1), 137-144	278	Article
5	Medepally, et.al(2010)Voluntary energy harvesting relays and selection in cooperative wireless networks, IEEE Transactions on Wireless Communications, 9(11) 3543-3553	277	Article
6	Durmaz Incel, O., et.al(2012)Fast data collection in tree-based wireless sensor networks, IEEE Transactions on Mobile Computing, 11(1), 86-99	230	Article
7	Wang, J., et.al(2010)A survey on sensor localization, Journal of Control Theory and Applications, 8(1), 2-11	228	Article
8	Mini, S., et.al(2014)Sensor deployment and scheduling for target coverage problem in wireless sensor networks, IEEE Sensors Journal, 14(3), 636-644	223	Article
9	Farash, M.S., et.al(2016)An efficient user authentication and key agreement scheme for heterogeneous wireless sensor network tailored for the Internet of Things environment, Ad Hoc Networks, 36, 152-176	218	Article
10	Anuradha, C., et.al(2016)Improving network performance and security in WSN using decentralized hypothesis testing, Journal of Chemical and Pharmaceutical Sciences, 9(3), 536-538	213	Article

Table 14 indicates the high cited top 10 wireless sensor network research publications in India for the selected ten year study period. From the study it is identified that, maximum number of 391 citations are received by Ojha, T., et.al. (2015)Wireless sensor networks for agriculture: The state-of-the-art in practice and future challenges, Computers and Electronics in Agriculture, 118, 66-84. Followed by 318 citations from Kuila, P., et al. (2014) Energy efficient clustering and routing algorithms for wireless sensor networks: Particle swarm optimization approach, Engineering Applications of Artificial Intelligence, 33,127-140. Third rank by 301 citations from Tyagi, S., et al. (2013). A systematic review on clustering and routing techniques based upon LEACH protocol for wireless sensor networks, Journal of Network and Computer Applications, 36(2), 362-645. The top ten highly cited wireless sensor network research publications in India are contributed 8 articles and 2 review papers.

Majour Finding and Conclusion

- During the study period total number of 11775 research publications are contributed in wireless sensor network in India. Maximum number of of 2058(17.48%) publications are contributed in the year 2019 and the compound annual growth rate 5.44.

- From the study relative growth rate is 0.88 in the year 2011 and 0.19 in the year 2019. At the same time doubling time is 3.61 in the year 2019 and 0.78 in the year 2011. So that this study confirmed that, relative growth rate is decreasing trend and doubling time is increasing trend.

- Majority of the authors in the field are preferred to publish their research works in two authorship mode with 5911(50.20 %) publications. During the study period, average degree of collaboration is 0.96, average Collaborative Coefficient is 0.58 and average Collaborative Index value is 2.70.

- During the study period CAI for single and two authorship contributions are increasing trend from 1st block year to 2nd block year. At the same time CAI is decreasing trend for more than three authors from 1st block year (106.71) to 2nd block year (97.39).

- During the study period, maximum of 82(15.36%) research publications are contributed by Das, A.K., India and his publications are received 1781(26.15%) citations, CPP is 21.72, h-index is 22 and RCI value is 1.70.

- During the study period, maximum number of 557(24.56%) publications are contributed by Anna University and it is received 3097(16%) citations, CPP is 6, h-index is 21 and RCI value is 0.63.

- Maximum of 461(20.21%) research publications are contributed by International Journal of Applied Engineering Research and it is received by 245(2.99%) citations, CPP is 0.53, h-index is 6 and RCI value is 0.15.

- Maximum of 251(37.08%) research publications are collaborated by United States of America. During the ten year study period total number of 1063 publications are collaborated by 71 countries.

- This study identified the estimated growth based on time series analysis statistical application will be expected in wireless sensor network research publications in India in the year 2025 is around are equal to 2277 and the year 2030 is around are equal to 2827.
- During the study period total number of 229 research publications are sponsored by the top ten funding agencies in the field of wireless sensor networks research publications in India. Out of that, maximum number of 51 (22.27%) research publications are sponsored by Department of Science and Technology, Government of Kerala.

- Maximum of 391 citations are received by Ojha, T., et.al.(2015). Wireless sensor networks for agriculture: The state-of-the-art in practice and future challenges, Computers and Electronics in Agriculture,118,66-84.

Conclutions

The overall ten year study period identified the wireless sensor network research publications from SCOPUS database is increasing gradually. Now a day's many institutions and research centers are doing many more research activities in the field of wireless sensor network . This study conclude that maximum of Indian authors research publications are collaborated by United States of America, followed by China. So that developed conutried are doing many more research activities in the field. At the same time developing countries are also want to do many more research activities in the field of wireless sensor network research, and provide the better service to the public.

Reference:

1. **Saraogi. M (2005**). Security in Wireless Sensor Networks, Department of Computer Science University of Tennessee.

2**. I.F. Akyildiz, Y.S.W. Su, and E. Cayirci (2002).** A survey on sensor networks, *IEEE Communication Magazine*, 40(8), 102–116

3. **Rabaey J , J. Ammer, J.L. da Silva Jr., D. Patel (2000).** PicoRadio: Ad-Hoc Wireless Networking of Ubiquitous Low Energy Sensor/Monitor Nodes, *IEEE Computer Society Annual Workshop on VLSI (WVLSI), Orlanda*, 9–12.

4**. J.P.Walters, Z. Liang, W. Shi, V. Chaudhary (2007).** Wireless Sensor Networks Security: A Survey. In: *Security in Distributed,Grid, and Pervasive Computing*, ed. byY.Xiao (Auerbach Publications, BocaRaton, 367–410

5. **http://www.xbow.com/** wirelesshome.aspx.Accessed on 12/01/2021

6. **Kifayat K, M. Merabti, Q. Shi, D. Llewellyn-Jones (2007).** The Performance of Dynamic Group-Based Key Establishment (DGKE) under Node Capture Attacks in Wireless Sensor Networks, *2nd Conference on Advances in Computer Security and Forensics (ACSF) 2007, Liverpool*, 12– 13

7. **Karisiddappa, C.R, Maheswarappa. B.S, & Shirol M.V (1990).** Authorship Pattern and Collaborative Research in Psychology, *IASLIC Bulletin*, 35 (2) 73-78.

8. **Bakri, A. & Willett, P (2008**). The Malaysian Journal of Library and Information Science-2006: a bibliometric study, *Malaysian Journal of Library & Information Science*, 13 (1) 103-116.

9. **Amsaveni. N & Vasanthi. R, (2013).** Authorship Pattern and Collaborative Research in the Field of Network Security, *Indian Journal of Applied Research*, 3 (1) 52 54.

10. **Thavamani, K. & Velmurugan, C, (2013)**Authorship Pattern and collaborative research work in Annals of Library and Information Studies, *Proceedings of the National Conference on Next Generation Library Services, SALIS 2013 – NGLIS* August, 16-17, Chennai

11. **Jena, Kamal Lochan. (2006).** A bibliometric analysis of the journal 'Indian Journal of Fibre and Textile Research, 1996-2004' *Annals of Library and Information Studies*. 53 (1) 22-30.

12**. Vimala, V & Pulla Reddy, V, (2009).** Authorship Pattern and Collaborative Research in the Field of Zoology, *Malaysian Journal of Library & Information Science*, 1 (2) 43-50.

13. **Zafrunnisha, N. & Pulla Reddy, V, (2009**). Authorship pattern and degree of collaboration in psychology, *Annals of Library and Information Studies*, 17 (1) 255- 261.

14. **Ravichandran.S and Vivekanandhan S. (2020).** Bibliometric Analysis of Solid Waste Management Research Publications (2010-2019) using SCOPUS Database, *International Journal of Library and Information Studies*, Vol.10 (4) ISSN: 2231-4911

15**. Velmurugan, C. and Radhakrishnan, N. (2017).** Authorship pattern and collaborative research on Nephrology literature in India: A Scientometric profile. *International Journal of Chemistry Pharmacy and Technology*, 2(1), 34-42.

16. **Suradkarpriya, A. and Dayadalve, P. (2016).** Authorship Pattern and Degree of Collaboration in Academic Emergency Medicine. *International Research: Journal of Library and Information Science,* 6(1), 112-121.

17. **Natarajan., K. and Kaliyaperumal, K. (2016).** Global Collaborative Patterns on Bioelectronics research output. *International Research: Journal of Library and Information Science,* 6(1), 35-46.

18. **Thavamani, K. (2015).** A Study of Authorship Patterns and Collaborative Research in Collaborative Librarianship, 2009-2014. *Collaborative Librarianship*, 7(2), 84-95.

19. **Rajendran P et al.(2013).** Scientometirc Analysis of Indian's Research output on wireless communication, *Journal of advances in Library and Information Science,* 2(3), 105 -111

20**.Vivekandhan S et al. (2016).** Pollution control research output in India from Scopus database: A scientometric analysis. *International journal of advanced Library information science*, 4(2):376-385.

21 **Ravichandran.S & Vivekandhan. S (2021).** Scientometric analysis of waste water management research publications from SCOPUS database during 2010-2019, *Library Philosophy and Practice (e-journal)*, 5139, 1-18.

22 Ashokkumar, L. and Gopalakrishnan, S. (2013). Indian literature output on Textile Research: A Scientometric Study. *Journal of Advances in Library and Information Science,* 2(4), 251-258.

23. **Mahapatra, M. (1985).** On the validity of the theory of exponential growth of scientific literature. *In 15th IASLIC conference proceedings*, Bangalore, 61-70.

24. **Subramanyam K (1983)**. Bibliometric Studies of research collaboration: A review. *Journal of Information Science.* 6(1), 33-38.

25. **Vivekanandhan. S et.al (2016).** Growth of literature in pollution control Research output: A Scientomentric Study. *Journal of Advanced in Library and information science,* 5 (2):170-178.

26**. Sivasamy.K et.al (2020).** Scientometrics Analysis of Leprosy Research Publications. *International Journal of Library and information Studies,* 10 (3): ISSN: 2231-4911.

27. **Ajiferuke, I., Burrel, Q. and Tauge, J. (1988**). Collaborative Co-efficient: A single measure of the degree of collaboration in research. *Scientometrics,* 14, 421-433.

28. **Garg, K.C. and Padhi, P. (2001**). A study of collaboration in laser science and technology. *Scientometrics,* 51(2), 415-427.

29**. Bharvi, D. and Khaiser, N. (2016).** Scientometric analysis of global solar cell research. *Annals of Library and Information Studies*, 63, 31-41.

30. **Jeyashankar R, Ramesh Babu B. (2013).** Scientometric Analysis of Leukemia Research output 1960-2011: An Indian perspective. *Asia pacific Journal of Library and information science*, 3(2), 1-15.

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